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1956-1957

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GEORGE C. HOUSER, 220 Clyde Street, Brookline 67, Massachusetts.

THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 5.00	Members	$ 5.00
Juniors	1.00	Juniors	2.00
Associates	10.00	Associate	25.00
Corporate Members	10.00	Corporate Members	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

THE RING TRICK

The time-honored ring trick always keeps the audience guessing, and if you like guessing games, perhaps you would like to guess how many tons of steel joint rings went into the construction of the City of Tulsa's 275,000-foot 72″ and 66″ Lock Joint Concrete Pressure Pipe water supply line. You'll find the answer concealed in the picture above.

But there's no guessing where the fabrication of these joint rings is concerned. Every ring used in the making of Lock Joint's flexible, self-centering and completely watertight Rubber and Steel Joint is carefully cut, rolled and welded. Then, to assure absolute roundness and exact diameter, every ring is sized on an hydraulic press to such close tolerances that any spigot ring will fit perfectly within any bell ring of like nominal diameter. This is only one of the many quality control measures which go into every phase of the manufacture of LOCK JOINT CONCRETE PRESSURE PIPE, to assure to the customer the highest type pressure pipe obtainable.

LOCK JOINT PIPE CO.

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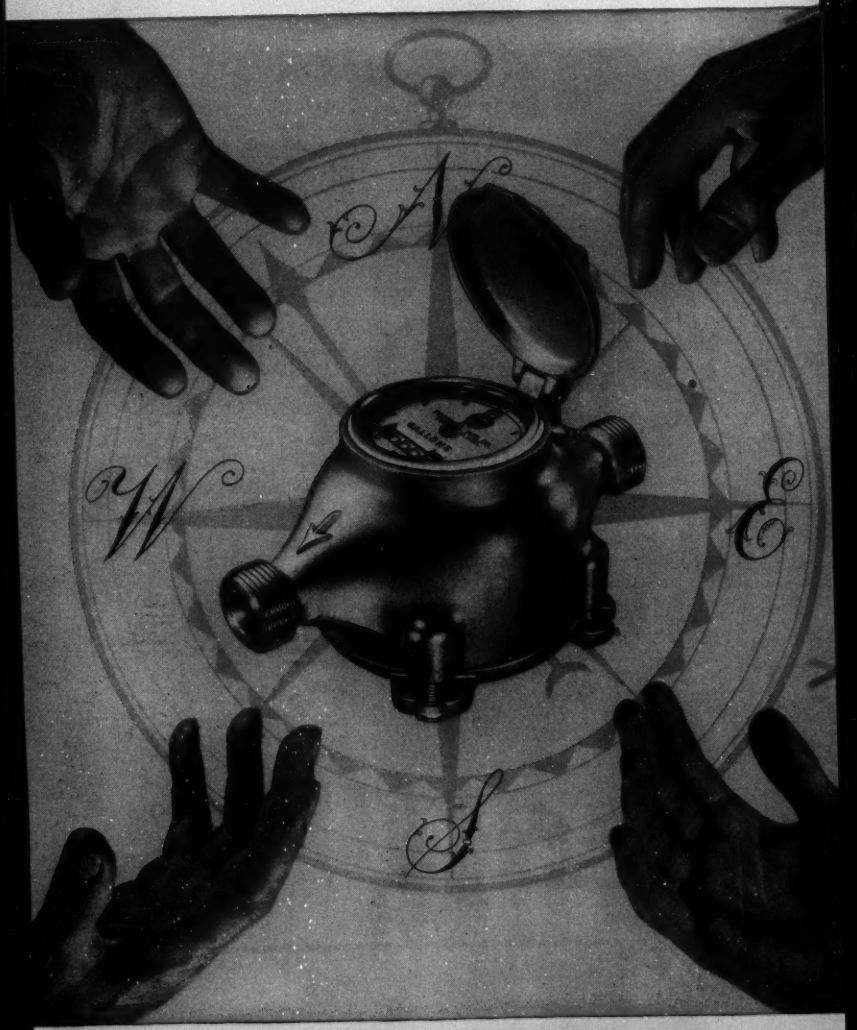
Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn. • Kansas City, Mo.

Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

IT SEEMS MOST

NEW ROCKWELL SEALED



EVERYONE WANTS REGISTER WATER METERS

From North, South, East and West . . .
The Response Has Been Terrific!

When a few months ago, we introduced the Rockwell Sealed Register Water Meter, *we* knew we had something good. But your tremendous acceptance and response to this new idea in metering has exceeded our fondest hopes.

Surprisingly enough, this business has come from *all sections* of the country . . . from areas where fogged registers or corrosion are normally not problems . . . and from towns, cities and water companies all over the United States.

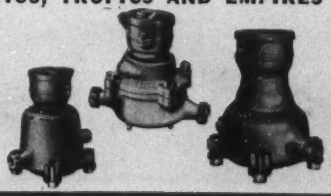
This is all very gratifying. It again proves that water works men *welcome change* when it means *betterment* . . . when a product such as the Rockwell Sealed Register Meter promises to make measurement more accurate, less troublesome and less costly.

Our thanks to all who have ordered these remarkable new meters. Production is being increased as rapidly as possible, but there will be unavoidable delays in filling everyone's needs. One thing is sure—production *will not* be rushed at the sacrifice of quality. Every meter shipped will be carefully made, inspected and tested. So please be patient. Rockwell Sealed Register Water Meters are well worth waiting for.

To the farsighted, we advise your anticipating next year's first quarter requirements for these new and better meters—now! *Rockwell Manufacturing Company, Pittsburgh 8, Pennsylvania.*

PROMPT DELIVERY ON ARCTICS, TROPICS AND EMPIRES

In spite of the tremendous acceptance of the Rockwell Sealed Register Water Meter, we will continue to make and sell our standard lines of domestic meters. These meters are produced in separate facilities so prompt shipments can be made—usually from warehouse stocks.



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The finest community protection by design

If you sat down and checked off the features that a well-designed hydrant ought to possess, you would find yourself describing a Mathews Modernized Hydrant

O-Ring seal available when specified

- It has a *replaceable barrel.* This is an outstanding safety factor, because it means that a Mathews broken in a traffic smashup can be operable again within half an hour and no excavation is necessary.
- It is a *dry-head* hydrant. The stuffing box plate is cast integral with the nozzle section with a screw-type stuffing box. This and the shield operating nut prevent abrasion, rust, corrosion or ice from interfering with the operating thread. It is always ready, no matter how severe the conditions.
- The main compression-type valve opens *against* water pressure. The higher the pressure, the tighter the valve—a positively leakproof construction.
- **OTHER QUALITY FEATURES** The operating thread cannot be bent. Head revolves 360°. Nozzle sections can easily be changed. Nozzle level can be raised or lowered without excavation. Bell, mechanical-joint or flange-type pipe connections.

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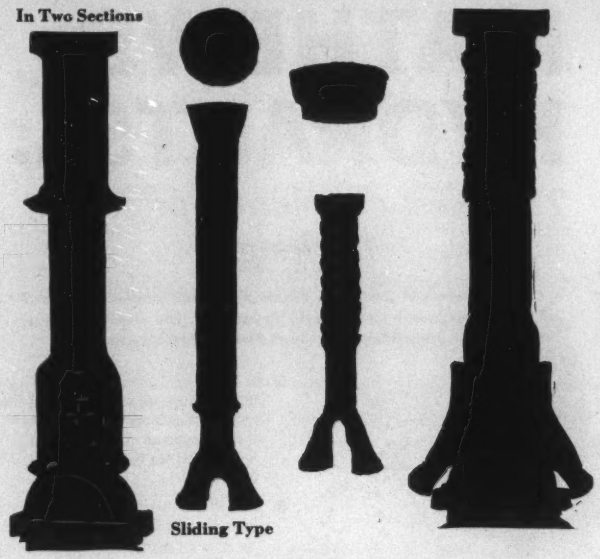

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Service. Valve. Roadway and Meter Boxes
Manhole Frames and Covers

CULPEPER, VIRGINIA

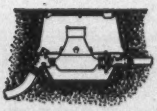
Rate Yourself as a METERologist...

CHECK HERE

- ☐ Do you believe in setting water meters so that they are most available for quick and easy reading?
- ☐ Do you provide installations which put meters in the proper position and protect them from dirt and damage?
- ☐ Are your meters connected into the line so that changing can be quick and trouble-free?
- ☐ Do you test meters periodically and maintain them for maximum accuracy?

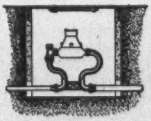
If you have checked all four you probably use Ford equipment. Don't be discouraged if your grade is off a little; the easy first step toward improving it is to send for a FORD CATALOG. IT'S FREE.

These Ford Products Make it Easy for you to be a METERologist



YOKE BOX

For shallow services the Yokebox provides protection to keep meter clean, easy to read and easy to change.

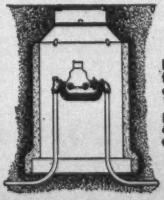


COPPERSETTER

A complete meter mounting that brings the meter up for easy reading and changing. Holds service line permanently connected.

COPPERHORN

Ideal setting for most basements with vertical service lines. Often saves more than its cost in pipe fittings.



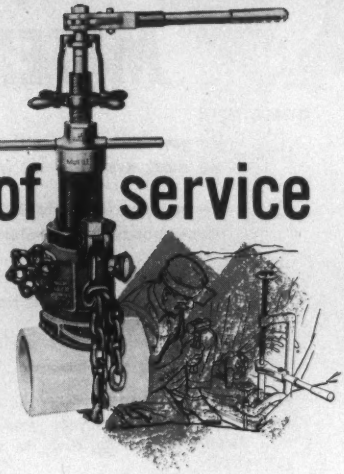
DOUBLE LID SETTING

Provides maximum frost protection in cold climates. The Yoke holds risers permanently braced and connected for easy meter changing.

FORD FOR BETTER WATER SERVICES

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

a century of service



In September, 1857, Hieronymus Mueller opened a one-man gun and repair shop in Decatur, Illinois. Mueller's inventive genius and insistence on perfection gained many customers; and the shop prospered.

In 1871, Mueller was appointed city plumber. At that time, a new water service was connected to the main by drilling a hole, almost through the main, and then inserting a drive stop into the partially drilled hole with a blow of a sledge. Usually the plumber was drenched, the trench flooded. It was often necessary to shut off the main, interrupting service to other customers while the connection was repaired.

Mueller was quick to recognize the need for a better method of making service connections and, in 1872, invented and patented the original water main pressure tapping machine, which drilled a hole in the main, tapped the hole and inserted the stop — all without interrupting service and without flow of water into the ditch. A vital need of the expanding water industry had been answered — the first of many such answers through a century of service.

MUELLER• today . . .

Mueller Co. looks to the future as it meets the needs of today. Mueller design and research engineers are already working on tomorrow's problems of the water, gas and oil industries. Five factories, equipped with precision machines, manned by skilled workers, manufacture quality products.

Upon the firm foundation established 100 years ago, Mueller builds for tomorrow and a second century of service to the vital water, gas and oil industries.

MUELLER CO. 100 YEARS SERVING the Water and Gas Industries QUALITY Since 1857

MUELLER CO.
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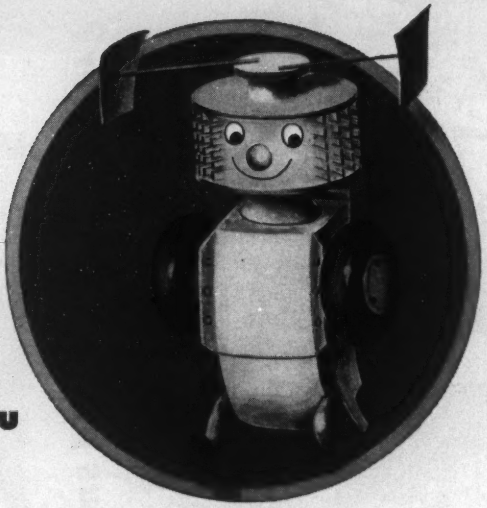
Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario



have you met

Dr. Centriline . . .

If not, you should! He can do things for you . . . like making your job easier and saving you money. He's a versatile and somewhat ingenious many-armed creature who specializes in cement-mortar lining the inside of pipes. And he's done this to over 4 million feet of pipe, too—eliminating corrosion and tuberculation . . . increasing flow capacity . . . reducing leakage . . . slashing pumping costs . . . and adding years and years of pipe life. If you'd like to learn more about Dr. Centriline and how he can work for you, just write or call for one of our descriptive brochures.

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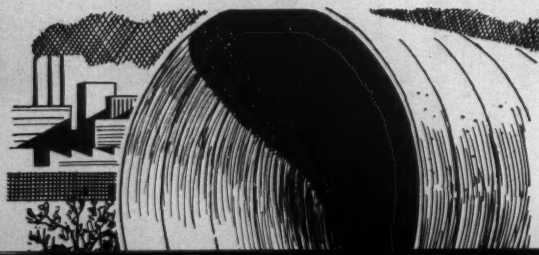
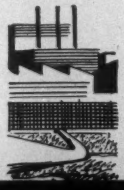
Branch Offices in Principal Cities of the United States, Canada and Latin America

• CEMENT-MORTAR LINING OF PIPES IN PLACE •

Men and property guarded

but how about our most precious possession . . . water?





How Badger Meters can help stop water waste—spur your community's progress

Safety costs millions — and they're dollars well spent. But reckless spending of water can destroy any community. If the situation is not already critical in your

Outstanding disc, turbine and compound meters — ⅝" through 12" — precision engineered for lasting service.

Badger disc, turbine and compound meters are adaptable to all local needs and water conditions. An example of Badger leadership is their exclusive compound meter which handles fluctuating water demands of factories, schools, theatres and apartment buildings—wherever the rate of flow varies through the day. Badger compound meters, like all other water meters in this complete line, assure maximum utility with full honest revenue.

Act now for your community's welfare and progress—new building, business and industry — all assured through adequate water, conserved by Badger meters. Write for literature or to arrange consultation with a Badger Meter representative.

Water is vital

Badger Meters have conserved it better for over 50 years.

Badger Water Meters

BADGER METER MFG. CO. — 2371 North 30th Street
Milwaukee 45, Wisconsin • *OFFICES IN PRINCIPAL CITIES*

ANOTHER FAIRBANKS-MORSE LEADER

Complex fire fighting system guards world's largest Auto Assembly Plant. Ford Motor Company at Mahwah, N. J. Protected by extensive system including two Fairbanks-Morse Centrifugal Fire Pumps.

One of the newest in the Ford chain of 16 assembly plants, the giant Mahwah installation is capable of turning out more than 1,000 cars and trucks in a single two-shift working day.

The system was designed by Ford engineers in collaboration with consulting engineers R. F. Giffels and V. E. Vallet.

The pumps chosen for this important service are two Figure 5814F Fairbanks-Morse horizontal centrifugals. One is a 6-inch pump with rated capacity of 1500 gallons per minute at a discharge pressure of 125 pounds. This is driven directly by a 150 HP Fairbanks-Morse type QZK induction motor at 1770 RPM. The second pump is even larger, an 8-inch F-M unit rated at 2500 GPM and driven through power transfer gears by a pair of 6-cylinder diesel engines. Actually there are three pumps, the third being a 1-inch Figure 5592- F-M centrifugal driven at 3475 RPM by a 15 HP motor.

Write or telephone to:

FAIRBANKS, MORSE & CO.

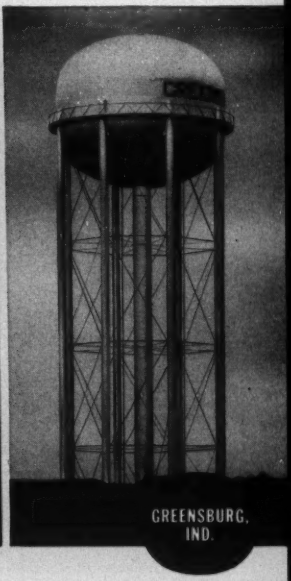
178 Atlantic Avenue **Boston 10, Massachusetts**

Telephone: LAfayette 3-3600

50,000 Gallons | 150,000 Gallons | 500,000 Gallons

GALENA, MD.

RACINE, WIS.



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...the capacities to serve your needs

...top economy and appearance, too!

PITTSBURGH · DES MOINES

Double Ellipsoidal

ELEVATED STEEL TANKS

Pittsburgh-Des Moines' Double Ellipsoidal Elevated Steel Tanks offer an advantageous combination of economical design and pleasing good looks, meeting today's exacting community standards. With very low head ranges in sizes to 300,000 gallons, and good head ranges up to 750,000 gallons, the Double Ellipsoidal tank design covers at low cost the greater part of all municipal water storage requirements. Write for our illustrated brochure detailing the complete range of PDM elevated tank types and capacities.

PITTSBURGH • DES MOINES STEEL CO.

Plants at PITTSBURGH, DES MOINES, SANTA CLARA, FRESNO and CADIZ, SPAIN

PDM ELEVATED STEEL TANKS

Sales Offices at:

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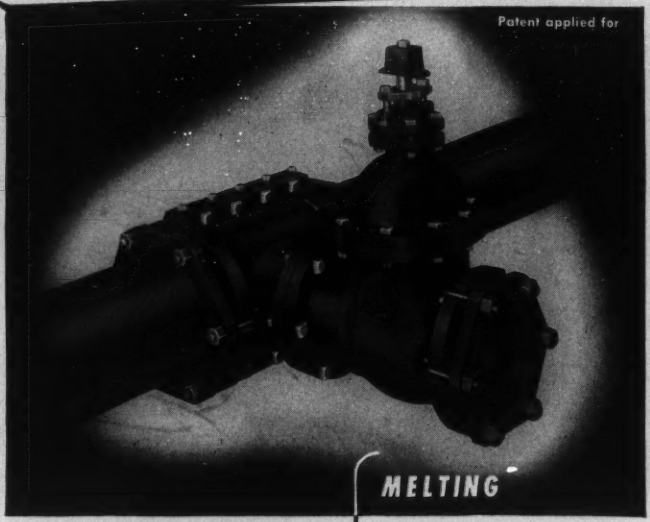
DES MOINES (8) . 925 Tuttle Street
DALLAS (1), 1229 Praetorian Building
SEATTLE, (1) . . . . 532 Wall Street
SANTA CLARA, CAL., 631 Alviso Road

THE FIRST MECHANICAL JOINT TAPPING SLEEVE AND VALVE



ELIMINATES { MELTING / POURING / CAULKING

A new *all* Mechanical Joint Tapping Sleeve and Valve, installed quickly and easily even by untrained workmen using a ratchet wrench. There are no joints to pour and caulk.

Installation can be made in wet trenches in any kind of weather.

The "Stuffing Box" type joints require no cutting or scarfing of rubber gaskets on job. Assemble Sleeve on main—attach the Valve, the installation is complete and the joints are permanently bottle-tight.

GATE VALVES
CHECK VALVES
FIRE HYDRANTS
INSERTING VALVES
TAPPING SLEEVES AND VALVES
WATER SERVICE BRASS GOODS

THE A. P. SMITH MFG. CO.
ESTABLISHED 1874
EAST ORANGE, NEW JERSEY

FLOOR STANDS
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TAPPING MACHINES
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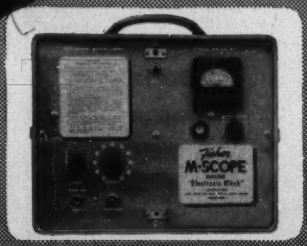
PIPE CUTTING MACHINES
CORPORATION TAPPING MACHINES

New!

TIME-$AVING COMBINATION LEAK DETECTOR-PIPE LOCATOR



THE M-SCOPE MASTER
Electronic Witch Combination

You're looking at the much-talked-about **NEW** M-Scope . . . the only dual-purpose that detects leaks **and** locates pipe. Its rugged, highly efficient electronic circuit, plus ease of use and portability, make this instrument one of the most welcome contributions to the water works industry.

Quick Facts

LOCATING A LEAK AT THE VALVE

FINDING A LEAK UNDER PAVEMENT

ONE MAN OPERATION

LOCATING A SERVICE

For greatest convenience and reliability, the M-Scope MASTER is equipped with a **built-in battery tester** for instant checking of battery condition in the field or elsewhere.

WRITE TODAY FOR SPECIFICATIONS AND PRICE!

PIPE LINE EQUIPMENT
JOSEPH G. POLLARD CO., INC.
PIPE LINE EQUIPMENT
PIPE LINE EQUIPMENT

Place your next order with POLLARD

It's from POLLARD It's the Best in Pipe Line Equipment

NEW HYDE PARK • NEW YORK

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Town of North Andover — New Lake Cochichewich Pumping Station

Pictured above are two De Laval two-stage centrifugal pumping units installed in a modern completely automatic water works station. Design conditions of each unit are 1400 GPM against 280 ft. TDH. Gasoline Engine auxiliary drive is included on one unit for emergency operation.
Our contract included installation of pumps, chemical equipment, intermediate piping and electrical control equipment.
Weston & Sampson, Consulting Engineers, prepared the plans and specifications, and supervised the installation of all equipment.

TURBINE EQUIPMENT COMPANY OF NEW ENGLAND

80 Federal Street **Phone LIberty 2-5993** **Boston 10, Mass.**

New England Representatives for

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TRENTON, NEW JERSEY

Up to 72"

LUDLOW VALVES

The water supply for thousands of people may depend upon a few large valves which must be reliable. Only a huge, specially equipped foundry, backed by giant tools, in a modern precision machine shop can supply this dependability. Ludlow has been the headquarters for large valves for nearly a Century.

LONG LIFE and DEPENDABILITY are built in. Ludlow Valves are fully bronze mounted. The two piece wedging mechanism is simple and rugged. The double disc parallel seat construction results in a wiping action that cleans the seats during the closing operation. The stems are special high tensile strength Ludlow manganese bronze with precision cut modified acme threads.

"NO POSSIBLE DIFFERENCE IN FIRST COST CAN OVERBALANCE THE PERPETUAL ECONOMY OF QUALITY."

17

Ask for Bulletin 547W

LUDLOW & Rensselaer

LUDLOW RENSSELAER **VALVES & HYDRANTS**

Since 1861 THE LUDLOW VALVE MANUFACTURING CO. Troy, N. Y.

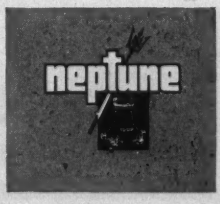
there's a cost that stays *Sealed* for seven years

All water meters are fine instruments. Any fine instrument loses accuracy as it wears. Because of this fact, written between the lines of any water meter price are two items you can't read for many years. Yet they are vital in choosing the lowest "total price."

First, as a meter loses accuracy, it gives away revenue. Before its first overhaul it may give away twice as much money as it seems to save in its "low bid" original price.

Secondly, to keep the meter accurate you may have higher repair costs over the years . . . or premature scrap-and-replace costs. Good meters often vary widely in this respect.

Tridents are preferred because they earn more and cost less in the long run. They never become obsolete. You modernize your Tridents as you repair. Ask your neighbor . . . or ask Neptune for details.



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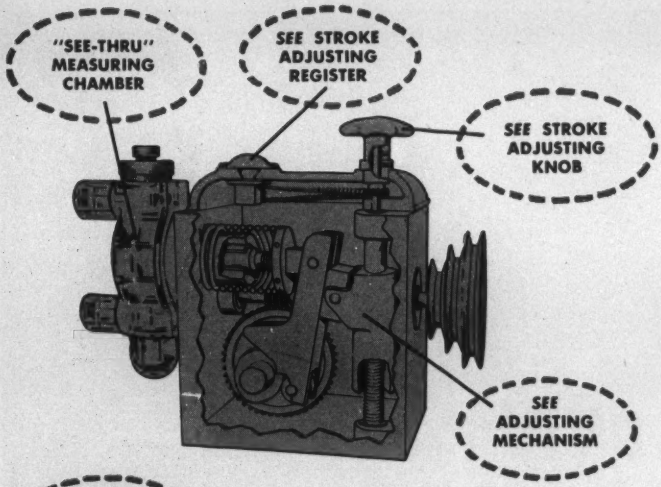
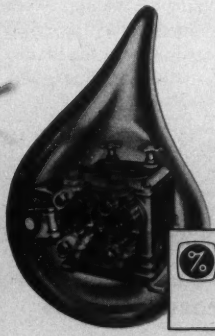


SEE THE DIFFERENCE!

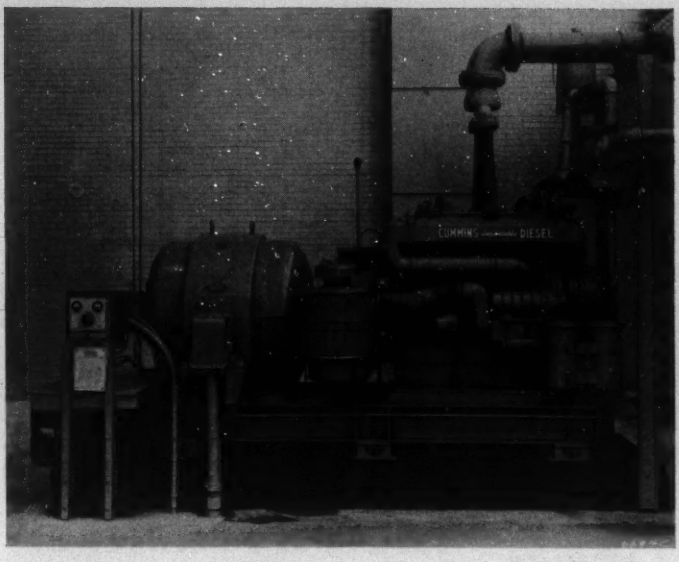
See for yourself the design features that make this one particular positive displacement chemical proportioning pump "the established standard of the industry". The cutaway view above shows the simplified internal mechanism of Proportioneers Chem-O-Feeder® which allows "in-motion" infinite adjustment of feed rate . . . plus operation features that put it in a class by itself.

- Provides maximum convenience and control
- Available in simplex, duplex, and triplex models
- Feed rates from 0.2 to 57 GPH
- Discharge pressures up to 125 psig
- Each pumping head can be set independently
- "See-thru" head handles many corrosive liquids
- Other reagent ends available for handling almost all other corrosive liquids



Request Bulletin 1225-2 for complete details. You can rely on the Chem-O-Feeder, the best all-purpose chemical proportioning pump available. Write to **PROPORTIONEERS, INC., 366 Harris Avenue, Providence 1, Rhode Island.**

PROPORTIONEERS
DIVISION OF
B-I-F INDUSTRIES
BIF METERS FEEDERS CONTROLS



CUMMINS MODEL NVHSGA-250 KW DIESEL GENERATOR SET

Lake Avenue Pumping Station
City of Worcester, Massachusetts

This dependable emergency generator set will automatically start and operate one of the 200 HP motors in the unattended pumping station. When automatically started, an instantaneous signal is transmitted to the Supervisor who calls the operating division. An engineer is expected to be at the Station in 20 minutes to manually shut down the set when he is sure normal power is available.

The designing and engineering of this Pumping Station was done by Camp, Dresser and McKee of Boston, Massachusetts.

CUMMINS DIESEL OF NEW ENGLAND, INC.

201 Cambridge Street
ALLSTON 34, MASSACHUSETTS

205 Lincoln Street
SOUTH PORTLAND, MAINE

Table of Contents

PAGE

Observations on the Nitrite Test
By E. A. Snow, Jr. 165

Water Supply of St. John's, Newfoundland
By Robert D. Mitchell 173

Pressure and Volume Survey in Arlington, Mass.
By Francis N. O'Hara 188

Maintaining Pipeline Coefficient "C" after Water-Main Cleaning
By William D. Monie and Harold B. Scales 203

Control of New England Floods
By Robert J. Fleming, Jr. 234

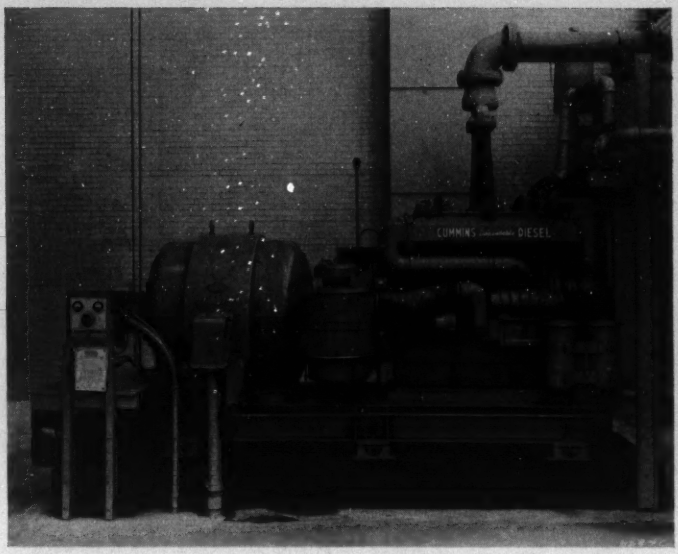
History and Operating Principles of the Magnetic Flow Meter
By Russell H. Babcock 243

Use of the Magnetic Flow Meter at Medfield, Massachusetts
By Edwin B. Cobb 251

Synthetic Detergents and Public Water Supplies
By Clair N. Sawyer and Devere W. Ryckman 261

Memoir of Horace L. Clark 277

Proceedings:
April 1957 Meeting 279
May 1957 Meeting 280



CUMMINS MODEL NVHSGA-250 KW DIESEL GENERATOR SET

Lake Avenue Pumping Station
City of Worcester, Massachusetts

This dependable emergency generator set will automatically start and operate one of the 200 HP motors in the unattended pumping station. When automatically started, an instantaneous signal is transmitted to the Supervisor who calls the operating division. An engineer is expected to be at the Station in 20 minutes to manually shut down the set when he is sure normal power is available.

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PAGE

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OBSERVATIONS ON THE NITRITE TEST

BY E. A. SNOW, JR.*

[Read at Chemists' Round Table, Dec. 15, 1955.]

Most water chemists are familiar with the Standard Methods determination of nitrite in water, using the reaction between sulfanilic acid and alpha naphthylamine to produce a pink color when nitrites are present. This reaction (1) has been used over 100 years with fairly satisfactory results.

In recent years several modifications of the basic reaction have been introduced. One that the author has found useful is the substitution of an alcoholic solution of dimethyl alpha naphthylamine for the straight alpha naphthylamine reagent (2). The latter has the disadvantage of discoloring and forming precipitates, so that it is often necessary to filter it before use. The dimethyl reagent, on the other hand, will stand up for months if kept in a refrigerator, with only a slight darkening after several months. The use of the dimethyl reagent obviates continual preparation or filtration of the reagent in this method.

Another method which has been used more particularly for field work in air pollution is the powder method. This reagent is made up in dry form as follows: N-1 naphthyl-ethylene diamine dihydrochloride 1.0 gm, sulfanilimide (2) 4.0 gm, and tartaric acid 95 gm. The mixed dry powder can be put up in envelopes containing 100 mg, which is enough for 1 test when dissolved in 10 ml of water. The powder keeps for one year if kept dry and in the dark.

There is a large number of substances that interfere in the nitrite test, but luckily only a few of these are likely to be present in drinking waters. Of the latter perhaps the disinfecting agents, such as chlorine and chlorine products, are the most common. When chloramine treatment is used, bacterial action on the ammonia may

* Senior Chemist, Amherst Laboratory, Massachusetts Dept. of Public Health, Amherst, Mass.

produce nitrite. Nitrogen trichloride imparts a red color in the reaction, giving a false reading for nitrite. The following ions give precipitates with the nitrite reagents: silver, mercurous, bismuth, antimonous, lead, ferric, auric, chloroplatinic and metavanadate (3). Cupric ion gives low results by catalyzing the decomposition of the diazonium salt produced. Of course, colored ions and natural color should be absent unless compensated for in reading the results. Chlorite ions and chlorine dioxide give an off-color orange yellow, even when no nitrite is present.

In some experiments with ozone gas in 1951 in our laboratory, we found that the nitrite reagents gave an orange pink color in 3 minutes and darker colors after 6 and 10 minutes' contact. Furthermore, it was determined that if the bright pink solution made with a standard nitrite solution with the reagents was exposed to ozone for 5 minutes, a slight yellowing of the pink took place, and after 10 minutes the solution was the same shade of orange pink which was produced by the use of the reagents and ozone alone.

The Non-Correlation of Nitrites with Coliform Results

Numerous routine water analyses have been selected, all of which show nitrites present, to see if there was any correlation with the coliform bacterial results. One might object that these analyses do not represent the average water analysis, and this objection is well taken. On the other hand, since most of our samples are taken because there is some suspicion of possible pollution in each case, this should show up any correlation between nitrites and coliform bacteria in even better light than if samples were chosen at random.

Of 135 samples taken, 66 showed the presence of coliform bacteria, or about 50% correlation. There was a suggestion of a possible relation between ferrous iron and nitrites, and of the 135 samples, 30 showed ferrous iron; of these only 17 showed coliform negative—again about 50%.

Of these 135 samples, even fewer than 66 would be definitely condemned. For example, if we use as a criterion coliform positive in 1 ml as well as in 5 10-ml portions, then only 33 of them would be considered grossly polluted. Here again only 50% of those showing coliform bacteria were polluted enough to be considered definitely unsafe, so that about 25% of all the samples were contaminated.

Occurrence of Nitrites in Drinking Water

The following public well supplies in Massachusetts have shown nitrites:

Supply	Free	Alb.	NO_3	NO_2	Cl	Fe
Brookline, tubular wells and filt. gallery	.009	.042	.202	.002	7.8	.08
Chelmsford, tubular wells	.007	.018	.875	.003	6.4	.20
Grafton, gravel-packed	.018	.009	.467	.005	6.4	.09
Hopkinton, new tubular	.002	.008	.833	.001	4.2	.07
Methuen, tubular, Pine Island	.069	.010	1.757	.002	9.1	.09
Methuen, Lone Tree Hill wells	.249	.035	.234	.008	6.0	.07
Sharon, dug well	.001	.012	2.775	.004	36.7	.05
Hadley	.034	.016	2.0	.025	5.0	.20
Amesbury, tubular	.085	.019	.055	.001	5.2	6.2
Attleboro, West Mansfield	.044	.027	.020	.004	4.1	1.75
Bourne, Pocasset tubular	.051	.007	.500	.001	19.6	.14
Bourne, Sagamore Mts. tubular	.004	.006	.030	.001	13.3	.27
Canton (Springdale tubular)	.014	.021	.575	.001	5.6	.14
Dover, tubular	.028	.005	1.50	.007	8.0	.70
Fairhaven, Nasketucket tubular	.004	.083	.353	.001	9.9	.12
Georgetown, filt. clear-water basin	.002	.007	.054	.001	3.9	.48
Granville (Center Water Co. well and spring)	.001	.008	.080	.002	1.4	.07
Great Barrington (infilt. gallery)	.012	.038	.166	.001	1.2	.07
Hingham filter galleries	.018	.035	.292	.001	7.8	.09
Manchester, dug well and tubular	.001	.020	1.16	.001	14.5	.50
Marblehead inlet of filter	.039	.039	.117	.002	18.8	1.51
Sutton, dug and tubular	.003	.023	2.57	.001	4.7	.08
Uxbridge, tubular	.000	.005	1.70	.003	6.7	.08
Ware, dug and tubular	.001	.006	1.46	.001	6.2	.07
Weston, Warren Ave. tubular	.000	.007	.298	.001	6.5	.27
Williamstown, Cold Spring	.001	.007	.233	.001	1.1	.06
Williamstown, Sherman Spring	.015	.053	.073	.001	1.3	.07
Woburn, gravel-packed A	.022	.026	.733	.005	15.6	.06
Avon, wells	.001	.011	2.650	.001	7.1	.10
Billerica, new large wells	.086	.085	.079	.002	9.1	.30
Bourne, Monument	.000	.006	.425	.001	10.2	.08
North Chelmsford, tubular	.127	.063	.248	.001	4.5	.40
Cummington, tubular	.002	.005	1.650	.002	2.8	.15
Dedham, large and tubular	.009	.022	1.000	.001	10.6	.10
Fairhaven, new wells	.002	.011	.720	.001	10.7	.08
Framingham, filter gallery	.119	.042	.083	.120	25.6	.11
Groton, large well	.033	.019	.020	.001	3.1	.12

Supply	Free	Alb.	NO_3	NO_2	Cl	Fe
West Groton, tubular	.009	.007	.045	.009	2.3	.39
Lowell, Boulevard tubular	.623	.059	.272	.003	4.8	6.02
Marion, new wells	.001	.005	.400	.001	13.6	.08
Marshfield (Humarock tub.)	.003	.005	.767	.001	23.2	.14
Methuen (Harris Brook tub.)	.046	.059	.400	.001	6.2	1.29
Newton, Well #1	.001	.018	.046	.001	7.1	.09
Scituate (Webster Meadow)	.039	.009	.315	.014	13.5	.06
Wayland, wells	.001	.008	.700	.001	5.3	.12
Woburn, filter gallery	.008	.055	.453	.005	13.4	.17
Bourne (Sagamore Keith)	.035	.008	.75	.030	8.7	1.46
Brookline, combined *raw*	.110	.085	.43	.015	10.4	1.27 (av. of 5)

That there is some connection between iron and nitrites seems evident after a perusal of the results in this tabulation (4). Especially where the iron is high, we often find nitrites and the free ammonia is generally higher than the albuminoid. Also, in cases of high nitrates and high iron we have a production of at least a trace of nitrites. Both of these situations point to reducing conditions at least partially caused by the iron. Examples of high iron and free ammonia are Amesbury, Attleboro, Dover, Marblehead, Billerica, North Chelmsford, West Groton, Lowell, Methuen and Hadley.

Examples of high nitrates (i.e. $>$ 0.50 ppm) are Chelmsford, Hopkinton, Methuen, Sharon, Hadley, Bourne, Canton, Dover, Manchester, Sutton, Uxbridge, Ware, Woburn, Avon, Cummington, Dedham, Fairhaven, Marshfield and Wayland. Of these only Dover and Manchester have high iron ($>$ 0.3).

The relationship of the different forms of nitrogen in lake waters and in the bottom muds is of interest also. Elemental nitrogen is fixed by some of the blue-green algae (notably *Anabaena*) and by bacteria at the ooze surface in the littoral or shallow regions.

Ammonia is the chief product of decomposition of both plant and animal proteins, and in the presence of oxygen (dissolved oxygen in lakes) it is oxidized to nitrates. In oligotrophic lakes nitrate is the normal form of nitrogen to be found, except for traces of nitrite and ammonia. During summer stagnation the nitrate may disappear completely in the upper strata of the epilimnion. Eutrophic lakes generally have higher nitrates, except that here, too, in the summer the abundance of algae may use up most of the nitrate, but it seldom

completely disappears. When the dissolved oxygen is reduced to a few tenths ppm in the hypolimnion, the nitrate suddenly disappears and the ammonia N increases with depth. At times there is a layer of nitrites between the nitrate and ammonia. Apparently the reaction at this layer is a production of nitrite and nitrogen gas at the expense of the nitrates. Most of the ammonia is produced by decomposition of proteins in the bottom ooze, and this dissolves and proceeds upwards as the summer stagnation period progresses.

Ammonia is formed under anaerobic conditions in the mud and in the hypolimnion when oxygen-free. At the mud surface in oligotrophic, and during the overturns in eutrophic lakes, nitrification sets in, due to bacteria in the presence of oxygen. The bacteria use both the energy and some of the CO_2 produced in the reactions, and the process is called a chemo-synthesis, since it requires no light as is the case in photosynthesis (5):

$$(NH_4)_2\,CO_3 + 3O_2 \longrightarrow 2HNO_2 + CO_2 + 3H_2O + 148 \text{ calories}$$

$$2HNO_2 + O_2 \longrightarrow 2HNO_3 + 44 \text{ calories}$$

By measurements of the redox potentials in muds and lake waters it has been found that there are definite potentials for three important oxid-reduction cycles:

$$\left.\begin{matrix} Fe^{++} \\ Fe^{+++} \end{matrix}\right\} 0.2\text{–}0.3 \text{ v. } \left.\begin{matrix} NO_3 \\ NO_2 \\ NH_4 \end{matrix}\right\} \begin{matrix} 0.4 \text{ –}0.45 \text{ v.} \\ \\ 0.35\text{–}0.4 \end{matrix} \left.\begin{matrix} SO_4 \\ S \\ H_2S \end{matrix}\right\} 0.06\text{–}0.10$$

Apparently as long as the redox potential remains above 0.25 we have an oxidized layer of ferric hydroxide complex in the mud and this traps all the nutrients in the mud until, by reduction from the anaerobic layers below, the redox potential reaches 0.2 v. and the soluble Fe^{++}, Mn^{++}, NH_4, P, etc., are released to enter the hypolimnion, especially during the fall and spring overturns.

It is possible that similar situations prevail in deep wells, and even in pipelines to a limited extent. Pipe deposits in mains, for example, generally have an inner layer of black iron sulfides, and ferrous ion as well as H_2S can easily be produced from this black layer.

The nitrogen cycle in water may be even more complex than it

is usually considered. This is partly due to the intimate connections of iron and its ions with the various forms of nitrogen, and all of these with the redox potentials prevailing at a definite time.

Since it has been observed that waters containing nitrates in contact with iron surfaces produce nitrite by reduction, it would seem that the nitrite determination has little, if any, sanitary significance. This is especially the case with well waters, since the use of iron pipes and casings is so prevalent.

To try and corroborate this observation by some simple experiments in the laboratory, a piece of 1″ x 2 3/4″ sheet steel was placed in a beaker with 50 ml. of a $> 1\%$ $NaNO_3$ solution. After 10 minutes' contact this solution gave a reading of 0.225 ppm nitrites. It is also known that many bacteria can produce nitrites from either ammonia or nitrates.

Another sample was used of 50 ml of water with 0.60 ppm nitrate and no nitrite. After 15 minutes' contact with the steel the solution had 0.008 ppm nitrite. In contact with the metal on standing overnight the first solution gave a reading of more than 0.810 ppm nitrite, showing that the longer is the contact, the greater the amount of nitrite produced (6).

Interpretation of Results

The most difficult part of water analysis is the interpretation of the results. Some authors have tried to set up limits for the various forms of nitrogen (7). These may be used as a guide, but there always are many exceptions to these rules.

Since nitrites should be considered along with the other forms of nitrogen and the chlorides, we shall consider some of the limits or rules for these results.

Free ammonia generally should not be over 0.010 to 0.020 ppm. If the water is nearly colorless, the albuminoid ammonia should not be over 0.150 ppm, except that in surface waters when plants are present it may be up to 0.400 ppm. Free ammonia may be quite high in well waters, due to reduction of nitrates and nitrites. The effect of iron pipes and iron in the water may cause this condition. Nitrites generally should not be over 0.010 to 0.020 ppm and in surface supplies should be 0.000. The results I have quoted do

not conform very well to this rule, since 5 out of the 48 public wells were over 0.010 and 51 out of 135 samples listed above. Of the latter only 14 would be condemned as definitely unsafe. Nitrates should not be over 1 ppm in surface waters and, in fact, they seldom are even this much, since algae and plants readily take up nitrates and utilize them for growth, forming protein nitrogen, part of which shows up in the albuminoid N test. Nitrates in ground waters should not be over 5 ppm, but here again there are many exceptions and waters apparently safe to drink may contain 10, 20 or more ppm. If a well sample has a high chloride content and low nitrate, this may be due to sink-drain wastes leaching into the well. On the other hand, chlorides slightly above normal and very high nitrate may show wash from fertilized fields. An example of this is a well in Whately with the following analysis:

Free	Alb.	NO_3	NO_2	Cl	Fe
.016	.006	20.8	.028	14.6	.15

Some samples can be very puzzling. For example, a well in Brimfield tested as follows:

Free	Alb.	NO_3	NO_2	Cl	Fe
.160	.180	.75	.180	11.0	.70

It also had a very disagreeable odor and poor bacterial results. As a check on possible pollution, uranine dye was used in the toilet, both in the house and across the street in a house on slightly higher ground, without any signs of the dye getting through. The whole mystery was cleared up, however, when the owner discovered a 40-inch snake had been trapped in the well and had decomposed.

The interpretation of analytical results in a sanitary analysis of water requires good judgment and common sense. It should always be based on comparison of the various forms of nitrogen present and the chlorides, as well as on the field survey and the bacterial results.

Summary

There are several modifications of the original Griess reaction for nitrites.

Interferences in the nitrite test include nitrogen trichloride, oxidizing agents such as chlorine, ozone and chlorine dioxide, and a number of metallic ions.

It has been shown that there is less than 50% correlation between the bacterial coliform results and samples containing nitrites.

The occurrence and interpretation of nitrites in drinking waters has been discussed. It has been pointed out that, in the case of well waters containing nitrites, there is generally a connection with the presence of iron. The presence of nitrites has very little sanitary significance in well waters of this type.

It has been shown that water samples containing nitrates in contact with iron metal can produce nitrite in a very short time.

References

1. American Public Health Association. "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes," 10th Ed., 1955, pp. 153-155.
2. Jacobs, M. B. "The Analytical Chemistry of Industrial Poisons, Hazards and Solvents," 2nd Ed., 1949, p. 356 and p. 358.
3. See 1.
4. Annual Reports of Mass. Dept. of Public Health, Div. of Sanitary Engineering, 1932-1945.
5. Ruttner, F. "Fundamentals of Limnology," 1953, pp. 79ff and 175ff.
6. Fair and Geyer. "Water Supply and Waste Water Disposal," 1954, p. 489.
7. Woodman and Norton. "Air, Water, and Food," 4th Ed., 1914, pp. 60ff.

WATER SUPPLY OF ST. JOHN'S, NEWFOUNDLAND

BY ROBERT D. MITCHELL*

[*Read September 19, 1956.*]

I presume that few here have had an opportunity to visit the island northeast of the United States known as Newfoundland. I have made a number of visits there in connection with the water supply of the capital city, St. John's. It occurred to me that problems there and in New England have sufficient common aspects, that it might be of interest to the Association to hear something about problems connected with the water supply of that city.

First let me describe briefly the area concerned.

The Island of Newfoundland and a section of the mainland, known as Newfoundland Labrador, together form the Canadian Province of Newfoundland. The capital of the province is St. John's. Newfoundland was a Dominion of Great Britain prior to 1933. From 1933 to 1949 it was a colony of Great Britain. In 1949 it united with the Dominion of Canada.

The province has a population of about 350,000 people and a total area of 155,000 sq mi. About 97% of the population lives on the island, which has an area of 42,734 sq mi. The city had a population of about 52,000 in 1951.

The city of St. John's is located on the Avalon Peninsula in the southeastern portion of the island. It has a small but excellent harbour on the Atlantic Ocean and extensive docking facilities. It has a temperate, marine climate with relatively high precipitation. The average temperature in the coldest month, February, is about 22° F., and in the warmest month, August, it is about 61° F. Total average annual precipitation is about 54 in., and annual average snowfall is about 100 in.

Plate I shows the city and surrounding area. The area within the city limits is 5.5 sq mi. The city is quite hilly, and the older and

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more developed section, westerly from the harbour, rises steeply in elevation from sea level to over 300 ft above sea level. Lower ground in the more sparsely and recently developed westerly portions of the city ranges in elevation from about 100 to 200 ft above sea level. A variation of more than 300 ft in ground elevation within the city has resulted in the separation of the water-distribution system of the city into a Low Level District and a High Level District.

St. John's is an important seaport and the eastern terminus of the trans-island railroad line of the Canadian National Railway System. It is the commercial and industrial servicing center of the country, as well as the principal center for the fishing industry. The city is the center for most of Newfoundland's governmental functions and contains many government buildings. There are numerous small industries in and near the city.

The "high value" commercial and business section of the city is generally adjacent to and immediately west of the harbour and contains many multi-story masonry and frame buildings. Buildings in most parts of the remainder of the city are closely spaced, old, frame structures which present a definite fire hazard. This indicates the need of adequate water-main capacities and pressures for fire-fighting purposes. Although there have been no recent fires of great magnitude in St. John's, in 1892 a fire completely destroyed two-thirds of the city. This conflagration resulted in property damage in excess of $20,000,000. Old records indicate that inadequate water for fire fighting was a factor in the failure to prevent its spreading.

There has been considerable residential growth in the western portion of the city in the past few years, including a sizable housing project constructed by the St. John's Housing Corporation, known as the Churchill Park Housing Project. This growth is continuing, and at present two new areas east and west of Churchill Park are being developed under jurisdiction of the municipality. The federal and provincial governments are financing these developments.

Large areas of land, in and adjacent to the westerly and southwesterly portions of the city, are suitable for future residential expansion and are gradually being developed as residential areas.

The municipal water system serves the entire city and some consumers outside the city limits. It supplies wholesale water to Torbay

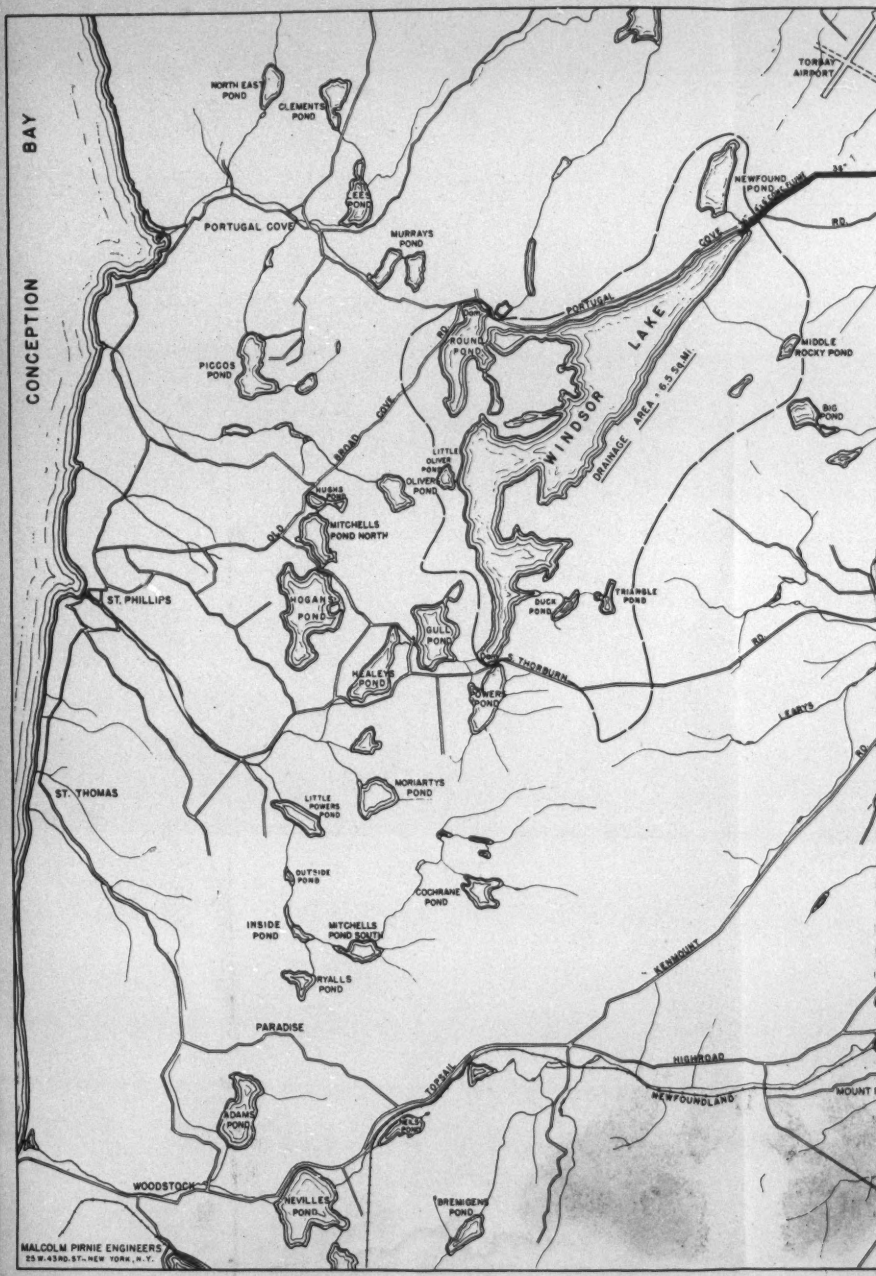
CONCEPTION BAY
NORTH EAST POND
CLEMENTS POND
LEES POND
PORTUGAL COVE
MURRAYS POND
PIGGOS POND
ROUND POND
PORTUGAL COVE RD.
WINDSOR LAKE
DRAINAGE AREA - 6.5 SQ.MI.
TORBAY AIRPORT
NEWFOUND POND
34"
RD.
COVE
MIDDLE ROCKY POND
BIG POND
BROAD COVE
LITTLE OLIVERS POND
OLIVERS POND
HUSKS POND
MITCHELLS POND NORTH
OLD
ST. PHILLIPS
HOGANS POND
GULL POND
DUCK POND
TRIBBLE POND
S. THORBURN RD.
MCALEYS POND
POWERS POND
LEARYS RD.
ST. THOMAS
MORIARTYS POND
LITTLE POWERS POND
OUTSIDE POND
COCHRANE POND
INSIDE POND
MITCHELLS POND SOUTH
RYALLS POND
KENMOUNT
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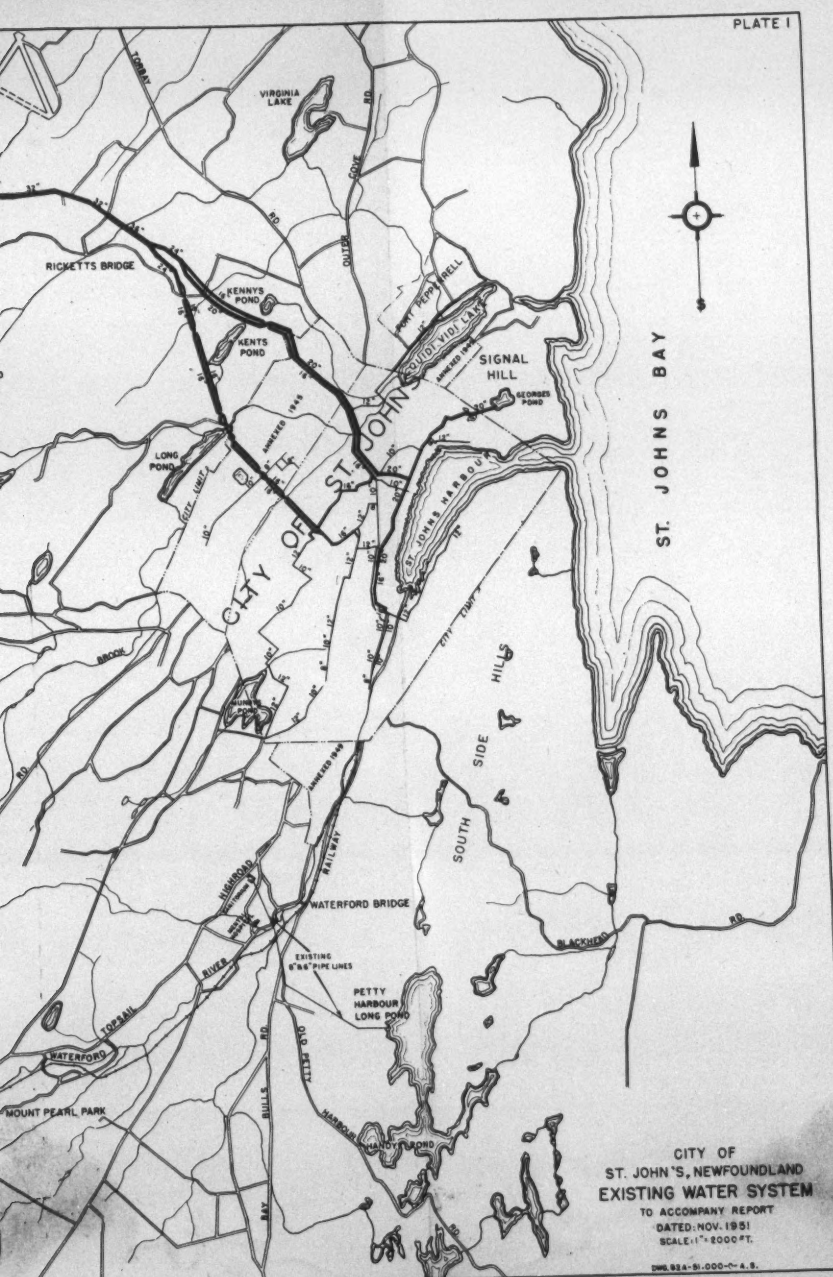
PLATE I


VIRGINIA LAKE
RICKETTS BRIDGE
KENNYS POND
KENTS POND
LONG POND
CITY OF ST. JOHN'S
SIGNAL HILL
GEORGES POND
ST. JOHNS BAY
ST. JOHNS HARBOUR
SOUTH SIDE HILLS
WATERFORD BRIDGE
RIVER
EXISTING 8"&6" PIPE LINES
PETTY HARBOUR LONG POND
OLD PETTY HARBOUR ROAD
MOUNT PEARL PARK
BLACKHEAD
CITY OF
ST. JOHN'S, NEWFOUNDLAND
EXISTING WATER SYSTEM
TO ACCOMPANY REPORT
DATED: NOV. 1951
SCALE: 1" = 2000 FT.
DWG. 824-51.000-A.S.

Airport and Pepperrell Air Force Base, and water to ships at the docks. The government-operated Mental Hospital and Sanitorium southwest of the city is connected to the new water supply from Petty Harbour Long Pond, located south of St. John's.

History of Water-Works System

The first water-supply system in the city of St. John's was a 6-inch main, extending from Georges Pond to Springdale and Water Streets, installed by the St. John's Water Company in 1846.

In 1859, the General Water Company purchased the system of the St. John's Water Company and, at the recommendation of British engineers, it began the construction of a new supply system from Windsor Lake. Water was first supplied to the city from this source in 1862. One of the great difficulties in constructing the original supply was the necessity of making a rock cut about a mile long and 10 to 35 ft deep, to permit gravity flow of water through a 16-inch main from Windsor Lake to the city. The capacity of this original installation was about 3 mgd, and in 1875 it was increased by replacing the 16-inch main in the rock cut with 24-inch pipe and using the old pipe partially to parallel the existing 16-inch main to the city.

Increased consumption and loss in carrying capacity of the cast-iron supply line between Windsor Lake and the city resulted in cleaning the main in 1886, but this improvement was short-lived because of recurrence of corrosion caused by the soft lake water.

In 1888 when the city of St. John's was incorporated, the water-works system was acquired by the municipality, and in 1903 the city embarked on a program of improvements, to provide adequate fire pressure in the higher portions of the city. These improvements, recommended by John Galt, Canadian consulting engineer, included a 7-ft-by-4-ft concrete conduit, 3,000 ft long, terminating in a screen house, to replace 24- and 16-inch cast-iron supply mains from the lake, and 8,000 ft of concrete conduit 3 ft in diameter, extending to a ½-mil gal capacity concrete reservoir. It also included the installation of the reclaimed 24-inch and 16-inch pipe, to strengthen the transmission system by constructing a main directly to the higher areas of the city and thus permitting the establishment of a separate High-Service

District. These improvements resulted in providing an adequate supply to the city for many years.

In 1915 the Council engaged the firm of Hazen and Whipple, Consulting Engineers, of New York, to study the system and recommend improvements which would increase the supply and the inadequate pressures in the high-level areas. This investigation resulted in the installation of a new, 20-inch, low-service supply main to Georges Pond, permitting the use of Georges Pond as a distribution reservoir on the low-level system; strengthening of the distribution system by the addition of 20-inch, 16-inch and 12-inch mains, and extending the intake facilities into Windsor Lake. These improvements were completed in 1920. The engineers also recommended acquisition of Petty Harbour Long Pond, south of the city, as a future auxiliary supply for the High Service District, and initial steps were taken by the city to obtain rights to the supply. This pond later was utilized by the government as an independent supply for the Mental Hospital and Sanitorium. In 1934, the city obtained a right to use it as a future supply, and this paper has to do with its development.

Exceptionally dry weather in 1927 and 1928 caused the level of Windsor Lake to recede 5 ft below normal, and the supply to the city was reduced to an alarming extent.

In 1928 the 21-year-old concrete conduit between the gate chamber near the reservoir and the screen house, which leaked badly, was replaced with a new 36-inch and 32-inch steel pipe; the watershed area of Windsor Lake was increased about 12% by adding Round Pond to it, and a new dike and spillway were constructed at the outlet of Windsor Lake. In 1932 an additional, 16-inch, high-level supply main was constructed and, in the early 1930's, meters were installed on commercial services. These improvements were the result of the serious water shortage in 1927 and 1928.

No major additions or improvements were made to the municipal water-works system in the period 1932 to 1951, when our engagement by the city began. The increase in water consumption by this time had reached a point that use exceeded the dependable supply in dry years. Fortunately, the city has not experienced an extremely dry period since 1928, and no extreme shortage has been experienced since that time.

Mains had gradually lost capacity because of the corrosive action of the water, and at times of heavy consumption, pressures were low in the higher areas of the city. Although some reinforcement of the distribution system had been made in recent years, main capacities in many parts of the city are inadequate for proper fire-flow requirements. The average consumption of about 175 imperial gallons per capita in 1950 was extremely high and indicated substantial leakage and wastage. It was necessary to carry extremely high pressures in low areas of both the High Service and Low Service Districts, in order to provide service to high areas in each District.

The city officials, realizing the need for a comprehensive review of the entire system, authorized us on March 20, 1951, to proceed with a study and report. At our suggestion, they also retained the Pitometer Co. to make leakage tests on the entire system of transmission and distribution mains and to determine the coefficient or carrying capacity of designated mains of various ages. This leakage survey has provided invaluable information as to reduction of excessive consumption and probable future consumption.

Description of Water-Works System Prior to New Construction

Plate I shows the main features of the St. John's Water Works, including Windsor Lake, the transmission facilities between the lake and the High Level and Low Level Service Districts, Georges Pond, and the larger mains of the distribution system.

Windsor Lake has been the source of supply for the system since 1862. Since it was originally utilized as a water-supply source, it has been enlarged by construction of a higher spillway and embankments to include Round Pond. At present it has a drainage area of 6.5 sq mi and a water-surface area of 1.8 sq mi at water flow-line elevation. The spillway can be raised up to 14 in. by use of flashboards. It provides the main control for high water elevation in the lake. The spillway discharges westerly to Gull Pond and Healeys Pond, and thence into Broad Cove River. A second and smaller dam with spillway is located at the original outlet of Round Pond on Portugal Road. This discharges into a small stream which flows in a northerly direction.

The drainage area is well wooded and the nature of underlying rock is such that it produces a soft water of excellent quality. It is relatively free from habitations and other sources of pollution. Windsor Lake provides an excellent source of gravity supply for the city up to the limits of its safe yield.

The present intake facilities are located at the north end of the lake. They consist of a 36-inch steel pipe, 625 ft long, extending from a concrete flume on the shore through the breakwater to a depth of about 20 ft in the lake. The pipe connects to a 4-ft-by-7-ft flume on shore, which contains gates to control the flow, and extends 3,000 ft to a screen chamber at the upper end of the steel pipe, which forms the upper end of the transmission system to the city. The invert elevation of the flume at the gate chamber is only about 10 ft below normal lake level, so that discharge to the city is substantially curtailed when the lake level is about 5 ft below normal.

The screening facilities comprise duplicate installations of fine wire-mesh screen, set in frames, which are removed each day and cleaned by hand. The intake, concrete connecting flume and screen chamber generally are in good condition and are adequate.

From the screen chamber, a section of 36- and 32-inch single steel transmission main extends approximately 8,000 ft to a point opposite an abandoned storage reservoir. This main was installed in 1928 to replace the existing concrete conduit, which was in poor condition and leaked badly. From the end of the steel main, parallel 24-inch cast-iron pipes extend about 500 ft to 30-inch cast-iron connections to the 30-inch-by-10-inch meter, which is adjacent to the meter house.

The meter house is a concrete structure which contains the meter register, valves to control flow to the 24-inch high- and low-service supply mains, and a chlorinator and appurtenances. The chlorine equipment was installed during World War II, but has not been used.

Transmission mains to the Low Level District consist of 400 ft of 24-inch C.I. main, extending easterly from the meter chamber; 16-inch and 20-inch parallel C.I. mains, extending 1,200 ft southeasterly along Portugal Cove Road and Rennies Mill Road to Rawlins Cross, and a single 20-inch C.I. main, 6,500 ft long, from Rawlins Cross to Georges Pond.

The transmission mains to the High Level District from the

meter chamber consist of 1,167 ft of 24-inch C.I. main and two parallel 16-inch C.I. mains, approximately 11,600 ft long, extending to Mayor Avenue and Merrymeeting Road.

These mains are 20 to 80 years old and have lost much of their original carrying capacity as a result of corrosive action of the water.

Following is a summary of the size, kind, and approximate length of the various kinds of pipe in the transmission systems:

TRANSMISSION-SYSTEM PIPE AS OF JULY 31, 1951

Size (in.)	Kind	Approx. length	
		Feet	Miles
36	Steel	4,070	0.77
32	Steel	3,970	0.75
30	C.I.	80	0.02
24	C.I.	2,630	0.50
20	C.I.	18,500	3.50
16	C.I.	35,200	6.67
		64,450	12.21

Georges Pond is located near and outside of the city limits on the westerly slope of Signal Hill, north of the harbour. It has an area of 13 acres at its flow line, which is approximately 309 ft above mean sea level. The 20-inch intake line has an invert elevation of 294.4 ft at the screen and gate chamber. It extends into the pond about 50 ft to an inlet 15 ft below the surface. The pond can be drawn down effectively about 10 ft, and at that elevation it has a capacity of about 35 mil gal, or about 5 days' supply for the city. The screen chamber is a rectangular structure containing two sets of fine screens, which are cleaned by hand.

Georges Pond has a very small drainage area. It is of adequate capacity and at proper elevation to serve advantageously as a low-service storage reservoir. It has been utilized by drawing water from it through the 20-inch supply main during periods of high consumption and permitting water to flow into it when demand is low. Control of flow into and from the reservoir was by means of hand operation of gate valves on the upper end of the low-service transmission main.

The following tabulation lists the size, kind and approximate length, as scaled from maps of the distribution-system mains.

DISTRIBUTION MAINS

Size (in.)	Approx. length Feet	Miles	Percent of total
20	3,650	0.7	1.0
16	8,000	1.5	2.1
12	22,500	4.2	5.8
10	26,650	5.0	6.9
8	42,355	8.0	11.0
6	265,635	50.3	68.7
4	17,450	3.3	4.5
Totals	386,240	73.0	100.0

As shown in the above tabulation, more than 73% of the mains in the distribution system are 6 in. or smaller in diameter. In general, the sizes of mains in the system are smaller than in most cities of this size.

There are no accurate detailed records of the age of the mains in the system. A considerable portion of the system has been installed for more than 75 years, and the average age of the mains in the system is at least 50 years.

The system was found to be reasonably well equipped with valves and hydrants. Of particular interest was the existence of about 40 fountains in the city, to supply water for persons who occupy approximately 400 dwellings. These are located generally in the poorer districts. Most of them have been in service for many years and are in poor condition. They are a source of water waste and also provide a sanitary hazard because of unsatisfactory drainage facilities. They are being abandoned gradually as better housing and economic conditions permit.

WATER CONSUMPTION

Studies of population trends led us to design new works for a future population of 75,000 persons, which is anticipated about 1980.

Water consumption at St. John's has been extremely high as com-

pared to cities elsewhere. It has ranged from an average of 150 to more than 235 gal per capita per day, expressed in Imperial gallons. This is equivalent to 180 to 292 U.S. gal per capita per day, which is considerably larger than the consumption range for municipalities in the United States, where per-capita water consumption generally is greater than in Canada and in Great Britain.

The exceptionally large consumption of water in St. John's has been recognized by a number of engineers who have investigated the system in the past and has been attributed to leakage of mains, service leaks and fixture waste. Generally, unmetered systems consume a greater quantity of water than fully metered systems, but St. John's water consumption is comparatively high for an unmetered system.

In 1950 the City Engineer attempted to reduce the high consumption by making a house-to-house survey of fixture waste. This was partially successful, and during 1950 and the early part of 1951, prior to the commencement of the leakage survey of the Pitometer Co., there was a gradual decrease in water consumption, although the number of water users increased substantially during the period.

Average draft of water in St. John's increased from about 6 mgd in 1919 to about 9 mgd in 1950. Based on available figures for the first 9 months of 1951, the 1951 draft will be about 7.5 mgd, or about 140 gal per capita. This reduction is the result of partial correction of fixture wastage and leaks in mains and services disclosed in 1950 by the City Engineer and in 1951 by the survey of the Pitometer Co.

Several factors contribute to high water consumption in St. John's. As shown by the Pitometer Co. survey, the principal factor is wastage from defective house plumbing fixtures. Another factor is the tendency for consumers to run water at night through fixtures, to avoid possibility of freezing of service pipes. This may be justified to some extent under conditions prevailing in St. John's, where winters are cold and many of the older services are too shallow. However, wastage from this practice would be curtailed to a great extent if the domestic services were metered, after proper protection from frost.

Works described were designed on the assumption that within the next 30-year period there will be an average consumption of 9 mgd from a population of 75,000 persons. To provide for unforeseen factors, such as exceptional growth and other contingencies, and to pre-

vent the need for drastic curtailment of use during extended dry periods, we recommended that the city increase its supply facilities to a safe yield of 10 mgd. This resulted in the need of an additional supply of 3 mgd.

Dependable Yield of the Windsor Lake System

It was previously mentioned that the Windsor Lake supply had a dependable yield of about 7 mgd. In considering this figure it should be realized that the contributing drainage area, including the lake itself, is only 6.5 sq mi and the yield is expressed in Imperial gallons. Based on U.S. gallons the yield is about 8.4 mgd, or almost 1.3 mgd per sq mi, including water area.

The above yield value was arrived at by a study of rainfall records covering a period of 75 years and reasonably good runoff records for a period of 14 years. Rainfall records establish the year 1927 as the driest year of record. During 1926, 1927 and 1928 the lake did not overflow for a period of 30 months and was drawn down to almost its minimum level of 5 ft below the spillway, corresponding to an estimated storage of 1,300 mil gal (Imperial). It had a yield during this period of practically 7 mgd.

As a verification of the above, rainfall and runoff records were correlated, and statistical analyses of safe yield were made by methods developed by Allen Hazen. This study confirmed the validity of using 7 mgd for safe yield.

Methods Studied to Improve Supply Facilities

In order to find the most suitable additional supply, we investigated all available potential water supplies in the vicinity of St. John's, including the possibility of additional development of the Windsor Lake supply. To the north, streams are small and are unsuitable. To the south, several possible sources are available.

Three most promising additional supplies for St. John's are additional development of Windsor Lake, Broad Cove River and Petty Harbour Long Pond.

The existing Windsor Lake intake structures limit drawdown of the lake to 5 ft at a flow of 10 mgd and 3 ft at a flow of 15 mgd. The safe yield of the lake has been computed at 7 mgd for a draw-

down of 5 ft. If additional storage could be made available, the yield would be increased somewhat. The physical character of the lake makes it impractical to lower the pipe lines to permit gravity drawdown, or to raise the lake level appreciably. The only practical method of utilizing more storage is by pumping from below the limits to which the existing intake system can function. In a dry period similar to the 1927 drought, when no water flowed over the Windsor Lake spillway for a 30-month period, we estimate that by pumping, an additional 1,300 mil gal of water, or an average of about 1.5 mgd, could be made available for use.

We also investigated the possibility of increasing the watershed area by gravity diversion. Only one small area remains which can be so diverted. This is the Powers Pond drainage area, which can be diverted into Windsor Lake by damming the pond outlet to raise its level about 4 ft to that of Windsor Lake. This diversion would add 0.8 sq mi to the drainage area of Windsor Lake. We estimate that by this method the drainage area of Windsor Lake could be increased to 7.3 sq mi and the dependable yield to about 7.5 mgd.

The Broad Cove River and its tributary, Rainbow Gullies, offer another source of additional water supply. The drainage area of these streams are generally west and south of Windsor Lake. Several possible dam sites exist on these streams that would permit developing a supply equal in size to the Windsor Lake Development, but all have the disadvantage of requiring pumping to Windsor Lake. The upper dam sites have drainage areas of about 3.7 sq mi and could be developed to a safe yield of more than 5 mgd. The lower dam site on the Broad Cove River has a drainage area of 6.5 sq mi and could easily be developed to yield 7.5 or more. Dams at these locations would be very costly. The yields from them are much greater than are needed now. For present needs it would be possible to build a pumping station without storage at the confluence of the Broad Cove River and Rainbow Gullies, and pump excess flows to Windsor Lake. In a dry period similar to that in 1927, this plan would add over 3.5 mgd to the available supply from Windsor Lake.

In connection with increasing Windsor Lake yield to about 10 mgd by diversion from Broad Cove River, consideration must be given to limitations of the intake works. A study of the hydraulics of the

system shows that the following peak rates can be drawn from Windsor Lake at various lake levels:

Peak flow (mgd)	Drawdown (ft)	Lake elev. (ft)
20	0	493.5
18	1.0	492.5
16	2.0	491.5
14	3.0	490.5
12	4.0	489.5
10	4.5	489.0

If the average demand from the system is 10 mgd and Windsor Lake is the only supply, excess intake and transmission-main capacity must be provided for peak consumption, even though Georges Pond and a new high-service elevated tank reduce peak flows from the lake.

The supply system should be able to supply at least 50% more water than the average, or 15 mgd. From the above tabulation, a drawdown of only 2.5 ft would be permissible. Therefore, if the Broad Cove River diversion is made, a pumping station would be required at the Windsor Lake intake for use when the lake was drawn down excessively. Since a pumping station on Windsor Lake would be necessary in any event, advantage should be taken of the available storage below the intake. This storage would raise the yield of the lake to 8.5 mgd, and the Broad Cove Pumping Development need be built to supply only 1.5 mgd. In the future, additional pumping and pipeline capacity to Windsor Lake could be installed as required. This plan would also require comparatively extensive high-service and feeder-main additions, as well as an expensive elevated storage tank in the High Service District.

Petty Harbour Long Pond lies about 2 mi south of the city. It has a drainage area of 2.1 sq mi, but an additional 0.5 sq mi can be added to its drainage area at low cost, by diverting small ponds now tributary to a brook discharging into Maddox Cove. Rights to use it as an additional supply were secured by the city from the government in 1934. The government was using the pond for a water supply to the Mental Hospital and Sanitorium, with a 6-inch and 8-

inch pipe extending to these institutions. In 1920 the government raised Petty Harbour Long Pond about 5 ft by constructing a dam across the outlet, in order to permit construction of satisfactory intake facilities. This dam was not provided with a proper cut-off and leaked badly. Unsuccessful efforts were made to stop the leakage, and to be used successfully as a water supply for St. John's, the dam would have to be rebuilt or replaced.

The original intake arrangement permitted only about 2.5 ft drawdown, and the dependable yield of the supply did not exceed 1.3 mgd.

We found, however, that if a new dam were constructed across the outlet to raise the pond elevation to permit a 10-foot drawdown, and the drainage area were increased by diversion to 2.6 sq mi, the dependable yield of the system would be increased to 3.5 mgd. Of this, 0.5 mgd is required for government use, leaving a net of 3.0 mgd for municipal use.

It did not appear advisable to obtain an additional supply from Windsor Lake by adding the small additional drainage area of Powers Pond or by pumping. The development of Powers Pond would necessitate the purchase of a large acreage of private land and the construction of a dam, and would not produce sufficient additional water to justify the expense.

Pumping from Windsor Lake would not sufficiently increase the yield to provide the needed additional supply. Also, it would not provide alternate supply and storage facilities available for use in both high- and low-service districts. This is an important consideration, as the entire supply of the city would pass for a considerable distance through a single conduit and supply main. The individual transmission mains to both districts are old and subject to occasional breaks, which disrupt service. An elevated storage tank of at least 1-mil gal capacity would be required in the High Service District.

The development of a pumped supply from Broad Cove River to Windsor Lake would produce the necessary additional yield. However, this would require pumping at Windsor Lake to meet peak demand consumption, as well as pumping at Broad Cove River. It would also provide no alternative to the Windsor Lake supply, and would necessitate cleaning and lining with cement all four transmission mains

at an early date and the construction of a storage tank in the High Service District.

Our studies indicated that Petty Harbour Long Pond would provide the most suitable additional water supply for the city. It would provide sufficient additional water to supply the needs of the city for the next 25 or 30 years; it would provide an entirely independent gravity supply to the city from an excellent drainage area, and it would avoid the necessity of constructing a large storage tank in the High Service District.

Water for fire protection and for peak domestic consumption would be available from two independent sources. In any water system it is always advantageous to have water enter from opposite directions. This tends to raise the hydraulic gradient and to increase capacity of existing feeder mains.

Program of Additions and Improvements

The project recommended for immediate construction by the city of St. John's consisted of the development of the Petty Harbour Long Pond supply works and transmission main to the city; treatment and control facilities on the Windsor Lake and Petty Harbour transmission mains and on the Georges Pond intake; cleaning and lining the two older transmission mains; addition of new feeder and distribution mains to the system; rearrangement of low-service pressure boundaries, with pressure-reducing valves where necessary; addition of hydrants, where needed; replacement of services; replacing air valves on transmission mains, and metering of all unmetered services.

The work done to date includes construction of a dam to raise Petty Harbour Long Pond 10 ft, new intake and treatment works for this supply, a new 16-inch transmission main to the city, pressure-reducing valve installations, and chlorination facilities for the Georges Pond distribution reservoir.

The Petty Harbour Long Pond Dam is constructed in two sections. One is an overflow spillway section, 145 ft long and 13 ft in maximum height, constructed on rock and abutting on rock at both ends. The other section, which is 280 ft long, crosses a valley filled with sand and gravel. This second section, constructed of earth, required an impervious cut-off to rock, because the valley fill was too

pervious to permit building a dam without a cut-off. No satisfactory material for an earth-fill cut-off could be found, so the dam was constructed with a concrete core-wall to rock. The core-wall extends about 25 ft below the original stream bed and 20 ft above it.

The dam was constructed by the Grant-Mills Construction Company of Toronto.

While the dam was being constructed, a new, 24-inch, cast-iron intake line was constructed from a deep point in the lake to a new screening chamber, located about 1,000 ft from the lake shore. This necessitated removing and replacing the old intake line, laid by the government in a deep rock cut.

The screening chamber utilizes a well-screen type of strainer with hydraulic backwash. Provision has been made for addition of chlorine and lime to the water, but the equipment is not in full operation as yet.

A new, 16-inch, cement-lined, cast-iron-pipe transmission main, about 16,000 ft long, has been constructed to bring Petty Harbour Long Pond water to the system. Pipe was shipped from foundries in England.

Principal distribution-system improvements are installation of pressure-reducing valves, to permit more uniform distribution-system pressures.

The chlorinating station at Georges Pond has been constructed but is not in full operation, pending equipment modifications found necessary for the operating conditions prevailing.

The cost of the work completed to date is about $470,000, as follows:

Dam	$270,000
Treatment facilities	85,000
Intake and pipe lines	115,000
Total	$470,000

Construction of the work was under the direct supervision of Mr. R. F. Martin, City Engineer of St. John's.

PRESSURE AND VOLUME SURVEY IN ARLINGTON, MASS.

BY FRANCIS N. O'HARA*

[*Read September 19, 1956.*]

For the purpose of introduction a background of the necessity of this survey in Arlington seems to be in order.

On May 26, 1954, the Crosby School burned with almost a quarter of a million dollars damage. The unquestioned responsibility for the great amount of damage lay upon the total inadequacy of the water supply. In view of this, the Town Manager, Edward C. Monahan, commissioned Thomas H. Egan, Deputy Fire Chief, the author, General Foreman of Public Works, to make a survey of the condition in the vicinity of schools, public buildings, churches, apartment houses, and residential areas.

We then drew up for approval an outline of proposed survey as follows:

Outline of Proposed Survey

1. Divide town into districts which will be surveyed.
2. Determine number of gallons per minute necessary to service area.
3. Determine size of main necessary to service area.
4. Determine number of hydrants necessary to service area.
5. Survey locations of hydrants as to ease of operation on any building in the area and comply with National Board of Fire Underwriters as nearly as possible.

Hydraulics

1. Determine pressure drops on hydrants tested and calculate amount of water available from the results.

Test Procedure

A. Test hydrants in groups such as would be used in serious fire in district to be tested.

* Superintendent of Public Works, Arlington, Mass.

B. Water should be drawn at sufficient rate so as not to be measurably affected by normal fluctuations in the line.
C. Time of tests should coincide with low drafts in the system (*i.e.*, night tests if necessary).

If five hydrants are to be in group tested, all hydrants should be observed by an observer who is equipped with a watch synchronized with all other observers, a gauge which can be easily read, a flashlight, hydrant wrench and Pitot tube.

Hydrant #1 will be a static pressure—*i.e.*, no nozzles opened—all others will be opened successively and static and dynamic conditions recorded to nearest ½ lb per sq in. This procedure seems involved, but after 3 or 4 times each observer will know his job and the series can be completed in 5 to 10 minutes.

2. If deficiency shows up, an investigation of the mains feeding the area directly and indirectly, back to a source known to be capable of delivering the necessary amount, should be made and corrections should be recommended to increase the efficiency to standard.

3. All operations of gates, hydrants, etc., testing for volumes or pressures, or any other test should be logged in Engineer's Handbook as to location, date and time.

4. A map of each district to be tested, showing present conditions as to mains, hydrants, and public buildings, should accompany final report.

5. A map of each district showing proposed changes should accompany final report.

6. A map should be prepared in schematic color, showing entire system as to size of mains, locations of gates, hydrants, and public buildings, type of service being blocked in in schematic color (*i.e.*, Red—High Pressure; Black—Low Pressure; Orange—Intermediate; and Green—Reduced High).

As a final suggestion, all gates should be located and operated to determine whether opened or closed. In 1938, a leak survey of the High and Intermediate Service showed 5 gates closed that should have been opened.

References used in this outline are from Babbitt and Doland, "Water Supply and Engineering", 2nd Edition, and the following

papers in JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION:

1. Hydrant Flow and Pressure Tests, conducted by Scott Keith, 1946.
2. Hydrant Flow and Pressure Test, Portland Maine, conducted by L. R. Smith, 1933.
3. Hydraulic Investigation of Water Distribution Systems in Field and Office, written by G. M. Fair, 1941.
4. Pitot Tube for Water Flow and Pressure Studies, written by H. B. Smith, 1930.

Although this outline may seem to be a final one, it may, in the course of our survey necessarily be changed, due to some extreme conditions which we now do not contemplate.

Then the town was divided into 21 Fire and Water Districts, and gallonage per minute necessary for adequate fire fighting was assigned to each district, with exceptions for unusual conditions and business areas. The districts were further broken down so that all hydrants in the district were used for test purposes and each test incorporated all the hydrants that would be used in a good working fire in each section of the area.

Explanation of Test Form

When the actual testing began, forms like the following were filled out on each test:

Time Started: Time Completed: Conditions
Test # District # Date

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pilot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per minute

Remarks

"Test No." is the sectional breakdown of the district containing those hydrants which might be used in fighting a fire or which might indicate hydraulic weaknesses in the supply lines.

"District No." is the designation of the areas which have been selected as districts because of various factors—natural boundary lines, pressure boundaries, extreme fire risks, and low fire risks. Natural boundaries are main street, town limits, etc.

"Date"—self-explanatory.

"Time"—self-explanatory.

"Conditions" are the color factors of the water. For example, "poor" indicates that by the time the water was shut off the condition of the water as to discoloration was still poor. "Fair" indicates that the water was in the process of clearing. "Good" indicates that almost immediately after opening the water was perfectly clear.

"Hydrants operated" indicates and locates the hydrants operated for the test of this particular area. No. 1 Hydrant is always a gauging hydrant, to obtain static and dynamic pressures. Other hydrants are opened as full as possible, to obtain a good flow without doing damage, and are measured for discharge when all hydrants are flowing.

"Static Pressure" is the residual pressure with all hydrants shut down before making the flow tests and also after making the flow tests.

"Dynamic Pressure" is the residual pressure with all the hydrants in the test, except #1, open as full as possible.

"Observed Pitot Reading" is the reading from the Pitot-tube indicator. By application of the formula,

$$Q = cd\sqrt{\text{Pitot Reading}},$$ in which

Q = quantity;

c = Coefficient of Pitot indicator (in this case it is 0.9);

d = diameter of orifice or nozzle diameter ($2\frac{1}{2}$ inches),

we obtain the quantity of the discharge of each hydrant in the test. The Pitot reading is the basis for the following column, headed "Quantity Gallons per minute."

"Quantity Gallons per minute" explained above.

"Estimated Quantity Available Gallons per minute" is based on formula:

$$\left.\begin{array}{l}\text{Gallons per minute}\\ \text{Discharge at 20\# psi}\\ \text{Residual}\end{array}\right\} = \left\{\begin{array}{l}\text{Total of entire}\\ \text{group of Hydrants}\\ \text{opened}\end{array}\right\} \times \frac{\sqrt{\text{Residual Static Press. (20 psi)}}}{\sqrt{\text{Residual Static} - \text{Residual Dynamic Pressures}}}$$

Actual Tests

The various subdivisions were tested separately and all irregularities of subnormal flows were noted, and proposed changes were indicated. Not until we hit District #9, Test #6, did any deficiency of a serious nature show itself. This Test #6 showed on a block of 4 streets only 850 gal per min available.

Test No. 6 — District No. 9 — June 30, 1954
Time Started 3:10 A.M. — Time Completed 3:25 A.M. — Conditions FAIR

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pitot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per min.	Remarks
#1 Mystic S. Farrington	80#	15#			850	
#2 Glen W. Rangeley			6	410		See letter to Town Manager —July 1, '54. Also see Notes #3, 4, 5, 6, 7, and 8, in Dist. #9, Proposed Changes in Water Mains
#3 Rangeley N. Mystic			8	480		

Test #7 on a similar block showed only 580 gal per min available, and one of the three hydrants had no flow available.

Test #8 under similar conditions showed 290 gal per min available, with two of the three hydrants showing no available water.

Test No. 7 District No. 9 June 30, 1954
Time Started 3:25 A.M. Time Completed 3:35 A.M. Conditions FAIR

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pitot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per minute
#1 Davis E. Mystic Bank	80#	0#			580
#2 Davis W. Mystic Bank			4	340	
#3 Kimball W. Emerson			4	340	
#4 Kimball E. Mystic			0	0	

Remarks

See Notes 3, 4, 5, 6, 7, and 8, in Dist. #9, Proposed Changes in Water Mains

Test No. 8 District No. 9 June 30, 1954
Time Started 3:45 A.M. Time Completed 3:55 A.M. Conditions FAIR

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pitot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per minute
#1 Fairview E. Mystic	75#	0#			290
#2 Draper W. Mystic Bank		4	340	340	
#3 Draper E. Mystic		0	0	0	
#4 Fairview 1/2 way down		0	0	0	

Remarks

See Notes 3, 4, 5, 6, 7, and 8 in Dist. 9, Proposed Changes in Water Mains

Test #9 showed a little better, but only because it included about 1,000 ft of 8″ pipe, and the two hydrants furnishing water were at a much lower elevation than the two hydrants which did not.

Test No. 9 District No. 9 June 30, 1954
Time Started 3:55 A.M. Time Completed 4:10 A.M. Conditions FAIR

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pitot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per minute
#1 Beverly E. Mystic	75#	0#			580
#2 Beverly 2nd hyd.			0	0	
#3 Beverly 3rd hyd.			0	0	
#4 Beverly 4th hyd.			4	340	
#5 Beverly 5th hyd.			4	340	

Remarks

See Notes 3, 4, 5, 6, 7, and 8 in Dist. 9, Proposed Changes in Water Mains

We immediately notified the Town Manager of the emergency in the deficiency in this area and other deficiencies we encountered of not so serious nature.

The Manager authorized us to contract with the National Water Main Cleaning Co. and to expedite the work as fast as possible, which we did. We cleaned about 7,500 ft of pipe and the deficiencies were relieved. However, other measures would have to be effected to make the system 100% efficient. The mains cleaned were Mystic Street from Mass. Avenue to Beverly Road; Park Street from Warren Street to Mystic Valley Parkway; Avon Place and Mt. Vernon Street from

Gray Street to dead end. The results of the cleaning are included in the following letters to the Town Manager.

August 11, 1954

MR. EDWARD C. MONAHAN, TOWN MANAGER
TOWN HALL
ARLINGTON 74, MASSACHUSETTS

DEAR MR. MONAHAN:

The cleaning of Mystic Street from Massachusetts Avenue to Beverly Road, Park Street from Warren to 8 x 6 reducer north of Exeter Street, and Avon Place from Massachusetts Avenue to dead end has been completed. The results are as follows:

Mystic Street 8" from Mass. Avenue to Summer Street now available 4250 gallons per minute. We drew 2980 gallons per minute with dynamic pressure of 65# and static of 90#, a pressure drop of 25.

Mystic Street 6" from Summer Street to Beverly Road now available 1100 gallons per minute which is about 95% of the amount 2450 ft. of 6" pipe can supply at this pressure. We drew 1250 gallons per minute with a dynamic pressure of 15# and a static pressure of 65#, a 50# pressure drop.

Park Street now has available 6000 gallons per minute with all feeds open. We drew 3370 gallons per minute with a dynamic pressure of 65 and a static pressure of 85. There was 1880 gallons per minute available from the six inch main with only one 6" feed at Warren Street.

Avon Place has 1730 gallons per minute available. Due to only one hydrant in the area on this main it was impossible to get a pressure drop reading but with the pumper outlet open not wide but about 3/4 this volume was available. Mystic Street area is not as satisfactory as it should be and while the volume is increased 150%, the side streets show need of cleaning but positive tests can not be made. It it our suggestion that an 8" reducing valve be installed on the present 8" connection to the High Service on Mystic Street at Beverly Road. Permission for this installation should be obtained from Commissioner Toole of the Metropolitan District Commission Water Division. Whether the 6" pipe on Mystic Street is renewed and enlarged, another feed to the area is necessary. This valve would operate 5# less than the present low service pressure and would open on a pressure drop of 5#. This valve would eliminate large shutoffs in case of breaks or maintenance operations and would bolster the present single feed and cut the length of 6" pipe approximately in half. We have taken the liberty to look into the cost of the valve and it would cost $429.00 f.o.b. Troy, N. Y. The weight of the valve is 670 lbs. Confirmation of this price accompanies this letter.

The total cost of installation would be approximately $1,150. broken down as follows:

Excavation	$ 100.00
Backfill & Haul	50.00
Installation	100.00
Miscellaneous Service & Materials	100.00
Manhole including Irons & Cover	300.00
Patching	50.00
Cost of Valve & Freight	450.00
Total	$1,150.00

Installation of this valve would delay renewal of 6" main on Mystic Street as long as 10 years.

Respectfully,

FRANCIS N. O'HARA, *Gen. Foreman*
THOMAS H. EGAN, *Deputy Chief*

* * * *

August 13, 1954

MR. EDWARD C. MONAHAN, TOWN MANAGER
TOWN HALL
ARLINGTON 74, MASS.

DEAR MR. MONAHAN:

The cleaning of the 6" main on Mt. Vernon Street has been completed; 1350 feet of main has been cleaned and the results have been very gratifying. On our first test we drew 580 gallons per minute with a static pressure of 88# and a dynamic pressure of 0#, or an available quantity of 500 gallons per minute. After cleaning we made the same test. We drew 1700 gallons per minute with a static pressure of 88# and a dynamic pressure of 33#, or an available quantity of 1900 gallons per minute.

Respectfully,

FRANCIS N. O'HARA, *Gen. Foreman*
THOMAS H. EGAN, *Deputy Chief*

* * * *

Deficiencies were noted in District 11 and District 12, which were easily correctible and are explained in detail in our letter of August 11, 1954, to the Town Manager.

August 11, 1954

MR. EDWARD C. MONAHAN, TOWN MANAGER
TOWN HALL
ARLINGTON 74, MASS.

DEAR MR. MONAHAN:

In the course of our survey we have made tests in the Intermediate Service and found our results to be from fair to poor and pressure drops ranging from

50# to 87#. Quantities available, necessarily with such pressure drops, were very low. We investigated and found both reducing valves, one at Gray Street and Highland Avenue 12", and one at Mass. Avenue and Highland Avenue 10", closed.

We received permission to open these reducing valves and on trying to get them synchronized found that due to lack of use, wear, and tuberculation, this could not be done satisfactorily. On Friday, August 6, 1954, we completely overhauled and rebuilt with new gaskets the 12" reducing valve on Gray Street and synchronized it with the Metropolitan District Commission feed on Eastern Avenue. The valve is now operating with an inlet pressure of 116# and an outlet pressure of 66#. Monday, August 9, 1954, the valve on Mass. Avenue, was completely overhauled and rebuilt with new gaskets and synchronized with the Metropolitan District Commission feed on Eastern Avenue. This valve is now operating with an inlet pressure of 154# and an outlet pressure of 86# fluctuating with 10# differential.

Now the Intermediate Service feeds entirely from the 12" feed of the Metropolitan District Commission on Eastern Avenue under normal operating conditions. With a pressure drop of 8# the valve at Gray Street and Highland Avenue will open and feed the area and with a further drop of 8# more the valve at Mass. Avenue and Highland Avenue will open and also feed the area.

Any closer adjustments of these valves might cause a backward flow of water through the Metropolitan District Commission Meter on Eastern Avenue and overflow the underground reservoir on Bellington Street.

Respectfully,

FRANCIS N. O'HARA, *Gen. Foreman*
THOMAS H. EGAN, *Deputy Chief*

At the start of our survey it was noted that the Calgon chamber was not operating and had not operated, due to deterioration of equipment. During the first part of our survey in Districts #1, 2, 3, 4, 5, 5A, and 6, we were greatly surprised and pleased at the amount of water available in these undersized areas. All pipes in this heavily populated area are mainly 6-in. This area had been cleaned extensively 9 to 12 years before our tests, and Calgon had been used constantly until about 3 months before the test began. Oxford Street, the location of the Crosby School and the primary reason for conducting the survey, is a prime example of the efficiency of cleaning in comparison with the two streets beside it as follows:

Test No. 1 District No. 6 June 25, 1954
Time Started 2:45 A.M. Time Completed 3:05 A.M. Conditions Good

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pitot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per minute
#1 Winter at Crosby Sch.	86#	35#			2920
#2 Winter S. Broadway			15	650	
#3 Winter N. Mass.			25	840	
#4 Mass. W. Winter			42	1080	

Remarks

Test No. 2 District No. 6 June 25, 1954
Time Started 3:10 A.M. Time Completed 3:20 A.M. Conditions Very Poor

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pitot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per minute
#1 Oxford W. Mass.	85#	0#			1260
#2 Oxford S. Raleigh			1	170	
#3 Oxford S. Broadway			7	440	
#4 Broadway E. Oxford			25	840	

Remarks

See Notes 1 and 2 in Dist. 6, Proposed Changes in Water Mains

Test No. 3 District No. 6 June 25, 1954
Time Started 3:25 A.M. Time Completed 3:40 A.M. Conditions Good

Hyds. Operated	lbs. per sq. in. Static Pressure	lbs. per sq. in. Dynamic Pressure	Observed Pitot Reading	Quantity Gals per minute	Estimated Quantity Available Gals per minute
#1 Grafton N. Raleigh	85#	70#			4580
#2 Grafton W. Mass.			50	1200	
#3 Mass. W. Grafton			35	1000	

Remarks

Oxford Street for some reason had not been cleaned in the previous cleaning, but it had been reported by myself five years previously, when I discovered its condition on an apartment installation. The tests show conclusively that cleaning plus Calgon had kept the coefficient of the pipes up to par. We received permission to put the Calgon back in operation, and it has been operating since this time.

Throughout the town there were sections that showed deficiencies in varying degrees. These were noted and put on sectional maps in color code showing degree of deficiency. Some have been cleaned and others will be cleaned each year for five years. Other changes will have to be made, such as extending mains to get rid of dead ends or enlarging present mains to provide proper feed. This will be done in the same period, at the end of which the system should be 100% efficient.

Recommendations

Recommendations for the better operation of the system are as follows:

1. Knowledge of water system by Chief Officers of the Fire Department. Without sufficient water the best-equipped fire department and the best-trained fire fighters can do very little towards bring-

ing a fire under control and accomplishing their assigned task of protecting life and property.

It is the duty of every chief officer of the fire department to have definite factual knowledge of the ability of the water system to furnish amounts of water to all parts of the municipality. A chief fire officer who does not know of his town's water-system deficiencies cannot utilize his apparatus to its greatest efficiency and may make mistakes in judgement in placing apparatus or manpower at a fire which will result in lost precious seconds and ultimately increased fire loss to the property, as well as possible loss of life.

2. That the Fire Dept. make semi-annual inspection of all hydrants and a complete record of the results of such inspections be kept on file by both the Fire and Water Depts. A copy of the enclosed report and procedure of inspection was delivered to Chief Richard J. Tierney of the Fire Dept. on December 4, 1954. (On order of Town Manager Edward C. Monahan, the Fire Dept. will assume the above responsibility January 1, 1955.)

3. The annual tests be made of conditions in areas that have been shown to be borderline, so as to determine the added deficiency. These tests should be made by the Fire and Water Dept.; in this way their knowledge of actual conditions will be improved.

4. A gate-operation machine should be part of the equipment of the Water Dept. This instrument is used in conducting leak surveys, and in the systematic operation and oiling of gate valves. Some valves in the system have seldom, if ever, been operated in the past 40 years.

5. For the location of hydrants in snow, there should be a painted metallic arrow, with figures to designate location of hydrant.

6. A color code should be adopted to designate availability of water:

e.g. Green = Excellent
Yellow = Fair
Red = Poor

This would greatly assist the Fire Dept. in locating pumping units at fires.

7. At least one *hydrant-thawing device* should be part of the

equipment on fire apparatus responding to an alarm of fire during the winter season.

8. A water dept. unit should respond to all multiple alarms of fire.

9. The Water Dept. must be notified immediately of all hydrants operated by the Fire Department during the winter season. These hydrants must be inspected to see that they are properly drained.

10. A long-range program of pipe cleaning should be inaugurated under the direction of the Supt. of the Dept. of Pub. Wks. He could select the water mains that should be cleaned so as to increase water pressures and volumes in deficient areas.

11. We recommend that the Calgon-Injection Chamber located on Broadway at Medford Street, used in connection with the low-service water system, be kept in operation. This chamber was installed in July, 1947; taken out of service, June, 1952; replaced in operation, October, 1954.

The use of Calgon is most important to prevent lowering of the coefficient of friction of water in iron pipe, and it also prevents discoloration of water. Its use is absolutely necessary after cleaning operations, or the benefits gained will be lost. The Metropolitan District Commission strongly recommends the use of Calgon. Treatment should be set up to include the High Service, Intermediate Service and remainder of the Low Service.

12. There are approximately 1,200 hydrants of various manufacturers: *e.g.* Corey, Eddy, Darling, Kennedy, Cambridge, Mueller, and Chapman. There are about 90 hydrants without 4½-in. outlets; some are situated in strategic locations. It is recommended they be replaced with standard types of hydrants, that conform with the requirements of the National Board of Fire Underwriters. The remaining Chapman hydrants are substandard, in that they have 4-in. inlets; these should also be replaced.

13. That a pitot unit be purchased for the Water Department. This is used to conduct leakage surveys, determine coefficients of mains, determine loss of head, and make flow tests, as well as test large meters. We now have many manholes throughout the town where this unit can be used to great advantage to the town. Therefore,

we recommend that this necessary and important unit be made part of the equipment for the Water Department.

Status of Recommendations

#1 and #2 have been in effect for one year and are working out perfectly.

#3 has been carried on spasmodically as conditions warrant, with gratifying results.

#4 has not been purchased.

#5 has not been adopted, as other factors enter the picture, but some designation will be adopted.

#6 is in the process of completion.

#7 has been adopted.

#8 Details are being ironed out to carry out this recommendation.

#9 has been adopted.

#10 is in process of five-year plan.

#11 has been adopted and is in process of completion.

#12 has been adopted and is in process of five-year plan.

#13 has not been effected as yet.

In closing I wish to thank the New England Water Works Association for the opportunity of presenting this paper on our survey.

MAINTAINING PIPELINE COEFFICIENT "C" AFTER WATER-MAIN CLEANING

BY WILLIAM D. MONIE* AND HAROLD B. SCALES†

[*Read September 19, 1956.*]

This paper deals with a fourteen-months' study of maintaining pipeline coefficient after water-main cleaning with the use of sodium hexametaphosphate. This test was conducted in Gorham, Me.

Gorham Village is one of the areas supplied by the Portland Water District. Because a large percentage of Gorham Village is above the gradient of Sebago Lake, the source of supply, it is necessary to pump water into the system by means of a booster pump. The booster pump is located at one end of the system, and a standpipe located at the opposite end floats on the system. The distance between the booster station and the standpipe is approximately 11,000 ft. The main feed from the booster station to the standpipe consists of an 8-in. water main with a small grid in the center of the system. A sketch of the system is shown in Fig. 1.

The pumping facilities of the booster station consist of an electrically-driven centrifugal pump with a capacity of 420 gpm, together with a centrifugal pump operated by a gasoline engine for use as a standby in case of power failure. The electrically-driven pump was installed in 1918 and had dropped in efficiency. The District was, therefore, interested in replacing this unit with a modern, more efficient pump.

In investigating to obtain the information necessary to design a proper pump for this location, it was found that the coefficient "C" for the 8-in. line between the booster station and the standpipe varied between 50 and 56. Before proceeding further we felt some action should be taken to reduce the head against which the pump would operate.

Further study revealed that this 8-in. main between the booster station and the standpipe had been cleaned 20 years ago. This fact

* Chief Engineer and †Chemist, Portland Water District, 16 Casco St., Portland, Me.

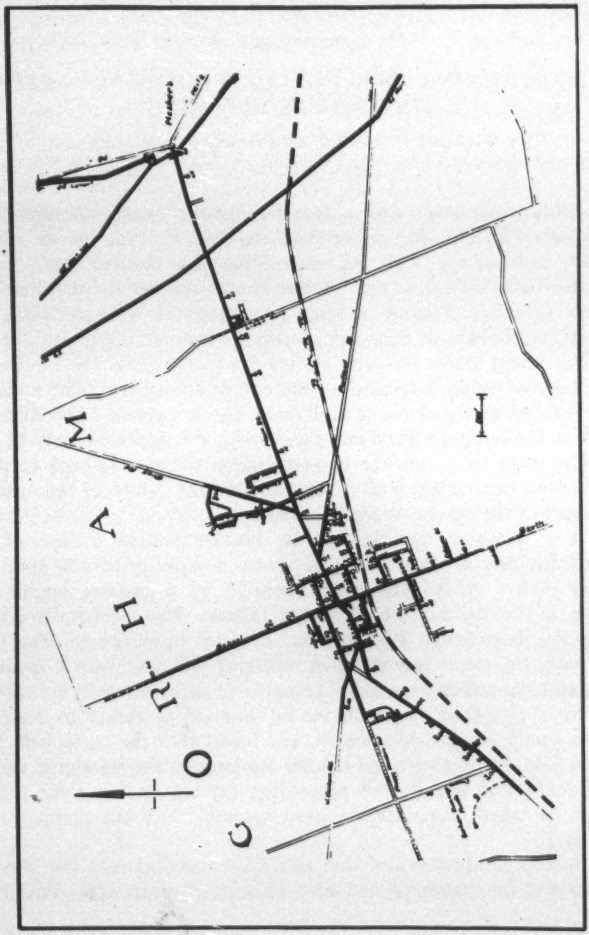


FIG. 1.

proves again that it is not feasible to clean a water main without retarding corrosion, either by chemical treatment or main lining. To replace this pipeline or adequately reinforce the system would be expensive. As Gorham Village is a small, isolated portion of the Portland Water District's system, we decided it would make an ideal system to study the effect of chemical treatment after pipe cleaning. We, therefore, decided to clean a portion of the 8-in. water main and make a careful study for a period of a year, to determine the effect of chemical treatment on the pipe coefficient. If this experience disclosed that we could sufficiently retard corrosion without any other ill effects, we would then proceed in cleaning all of the 8-in. pipe from the booster station to the standpipe, together with some of the 6-in. grid. We delayed ordering a pump replacement until the end of the study, so that the pump design would be proper for the cleaned condition of the main.

After study we decided to use sodium hexametaphosphate because of its ease of application and apparent success in other locations. We also felt that this treatment was more fool-proof for automatic station operation. If this treatment was not successful, we would then try lime or a combination of lime and metaphosphate in our study. The sodium hexametaphosphate we used was obtained from Calgon, Inc., and therefore, for simplicity we shall hereafter refer to hexametaphosphate as Calgon.

For one month prior to cleaning we added Calgon at approximately 4 ppm. The reason for this prior treatment was two-fold: (1) that we might possibly obtain some softening of the tubercles, and (2) that the dispersing effect of Calgon might aid in the removal of the scale deposit.

On June 21, 1955, a 4,000-ft section of the 8-in. water line on the discharge side of the booster pump was cleaned by the use of the conventional pipe scraper. We felt that this section would be the hardest section to maintain a high pipeline coefficient, due to the fact that the pump operates an average of five to six hours per day, and the remaining time the condition of this section of the pipeline is similar to that of a dead-end. Fig. 2 shows the type of scraper used. Fig. 3 shows the scraper entering a section of pipe, which was later sleeved into the main at the point where the cleaning operation was to start.

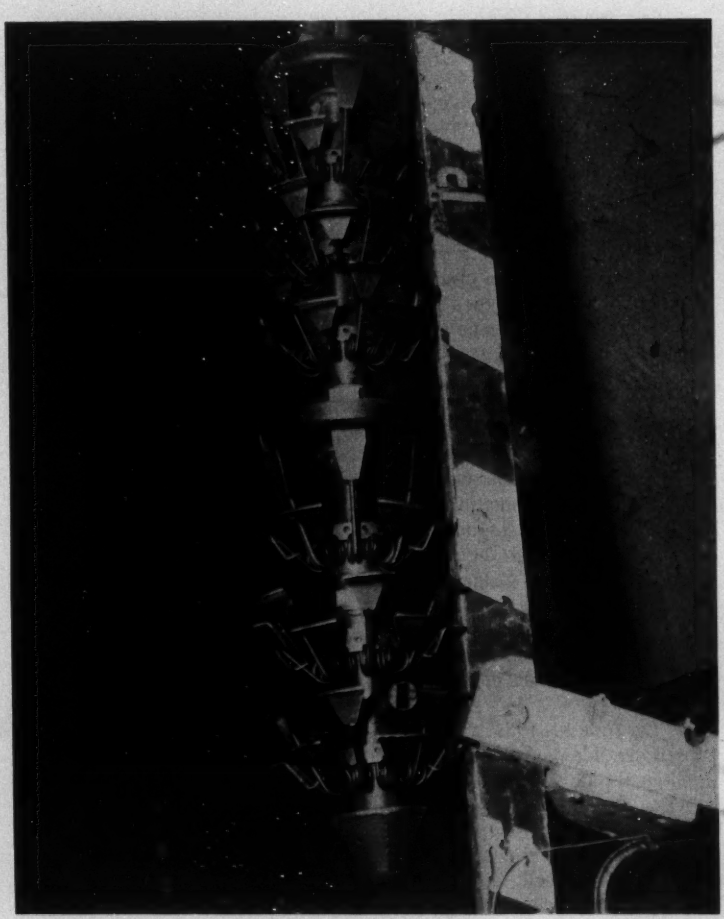


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FIG. 2.

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FIG. 3.

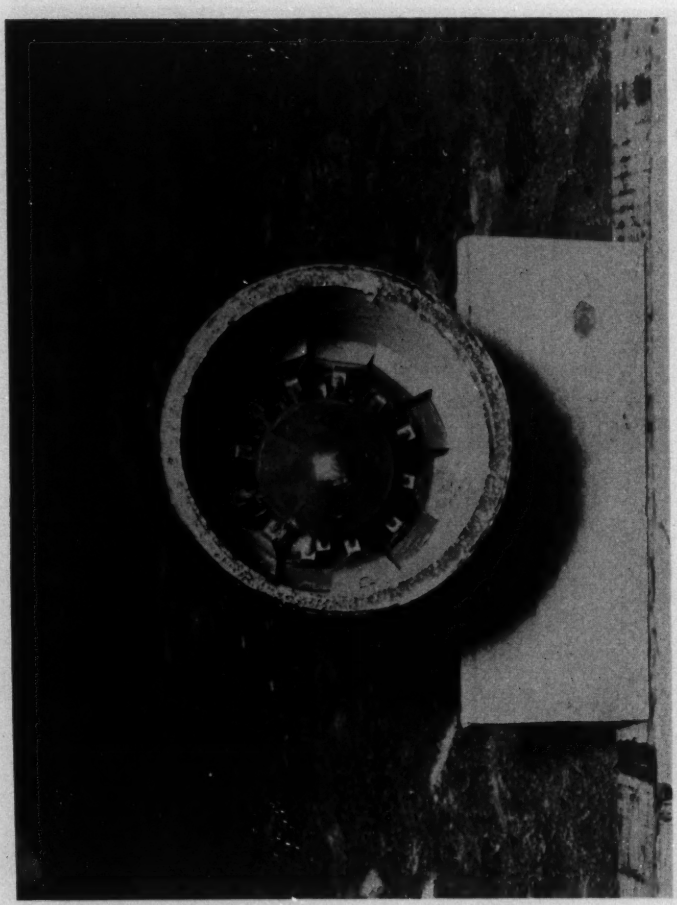

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FIG. 4.

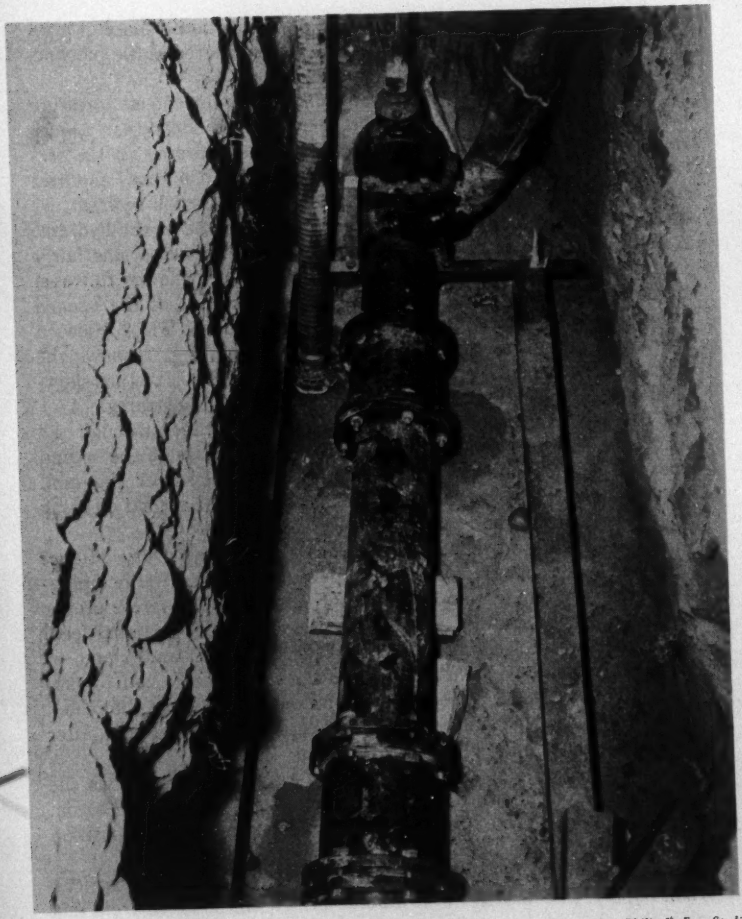

FIG. 5. *Philip K. Frye Studio*

Fig. 4 is a picture of the scraper in the above-mentioned piece of pipe. Fig. 5 shows the piece of pipe with the scraper inserted in the pipeline, ready to start operation.

In the cleaning operation we maintained only enough pressure behind the scraper to make the scraper travel no faster than a very slow walk. Before starting the scraper, all the hydrants on the section of the main to be cleaned were opened, and all services and grid connections were shut off. As the scraper came to each hydrant, its travel was stopped as the water pressure was released at the hydrant. We allowed the hydrant to remain open until the water became fairly clean. The hydrant was then closed and the scraper allowed to travel to the next hydrant, etc., until the scraper came out of the opened end of the pipe at the end of the section to be cleaned. Fig. 6 shows a hydrant discharging water ahead of the scraper. Fig. 7 shows the scraper as it came out of the cleaned section. Fig. 8 is a picture showing the tubercles in a section of the 8-in. pipe prior to cleaning.

In each case of pipe cleaning we ran the scraper through the entire section twice. Prior to running the scraper through the second time, one-half pound of Calgon Composition T Glass per thousand feet of pipe was placed behind the cleaner. After the second cleaning the pipe was flushed and put back in service.

The Calgon was applied by means of a Heavy-Duty Midget Chem-O-Feeder, manufactured by Proportioneers, Inc. The pumping-station delivery rate was approximately constant, and therefore proper dosage was easily obtained without the necessity of proportional feed. The initial rate of feed consisted of 7 ppm of Calgon and 6 ppm of Calgon Composition T Glass. This treatment was continued for approximately two weeks after cleaning, and the T Glass was eliminated and Calgon fed for an additional two weeks at the rate of 9 ppm, after which the Calgon was decreased to 5.5 ppm.

The Calgon Composition T Glass has a zinc base and has the property of laying down a much faster coating than regular Calgon. The authors feel that it is of the utmost importance that Composition T Glass be used immediately after cleaning.

Table 1 shows a typical analysis of the Portland Water District's water supply, as collected in the laboratory. It will be noted from this table that Sebago Lake water is very soft, with a pH of 6.7 and a

low total-solids content. The calcium content is 4.5 ppm. The iron content is only a trace.

In using hexametaphosphate it is necessary that the water supply to be treated have a minimum calcium content of 1 ppm for each 4 ppm of Calgon added. This amount of calcium is necessary to combine with the Calgon, to form the complicated chemical complex which protects the pipe. If more than 4 ppm of Calgon is added for each part of calcium in the water, the Calgon itself would then be corrosive. If there is not sufficient calcium present for the initial high treatment necessary, it can be added in the form of calcium chloride or lime.

TABLE 1.—CHEMICAL ANALYSIS OF PORTLAND WATER SUPPLY (PPM)

Chlorides	2.4	Silica (SiO_2)	6.0
Nitrates	0.05	Aluminum (Al)	TR.
Nitrites	TR.	Sodium (Na)	1.7
Free Ammonia	0.028	Potassium (K)	1.6
Albuminoid Ammonia	0.074	Calcium (Ca)	4.5
Required Oxygen	2.8	Magnesium (Mg)	1.0
Dissolved Oxygen	11.1	Manganese (Mn)	.0
Hardness	14.0	Iron (Fe)	TR.
Alkalinity	5.4	Sulphates (SO_4)	6.0
pH	6.7	Carbonates (CO_3)	6.0
Carbon Dioxide	1.0	Fluorides	0.
Iron	TR.		
Total Solids	27		
Loss on Ignition	11		

Fig. 9 shows the coefficient obtained on the 4,000 ft of cleaned main over a period of approximately 14 months. It will be noted that the original C value immediately after cleaning was 130. We felt that this coefficient was unreasonably high, but a check of the meter, gauges, elevations and calculations disclosed the coefficient to be correct. Subsequent tests taken two months and four months after cleaning showed that the coefficient value was increasing to a C of 132½ on October 20, 1955. These results were extremely unreasonable. It is fairly obvious that there was either leakage or consumption between the two points that were used to determine the coefficient. Samples were taken for iron determination at intervals along the 4,000-foot section of cleaned main, and we found a decided drop in

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FIG. 6.

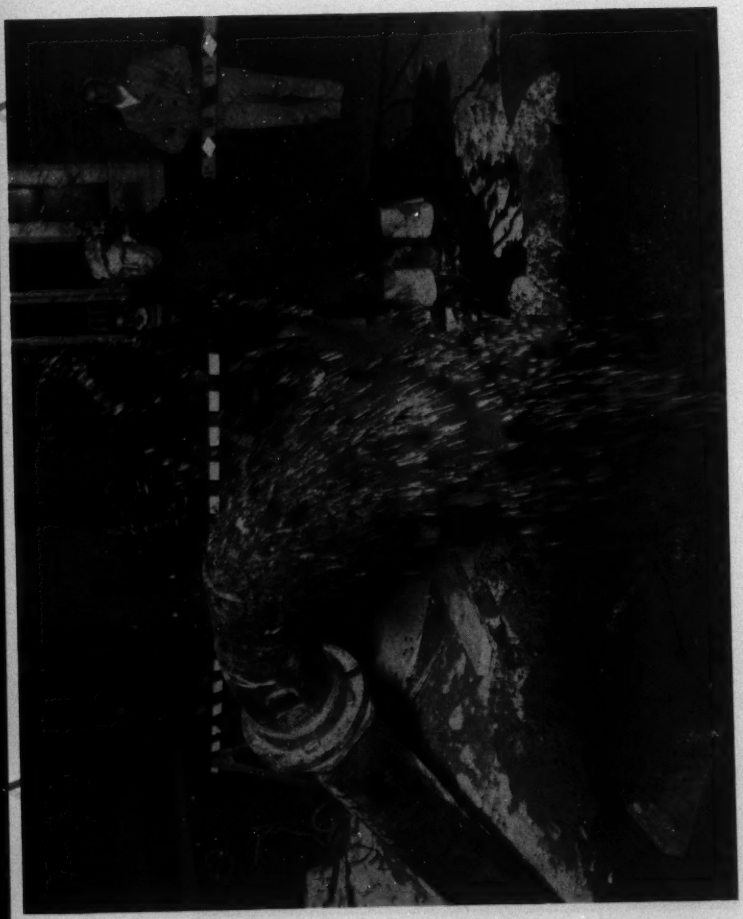

FIG. 7.

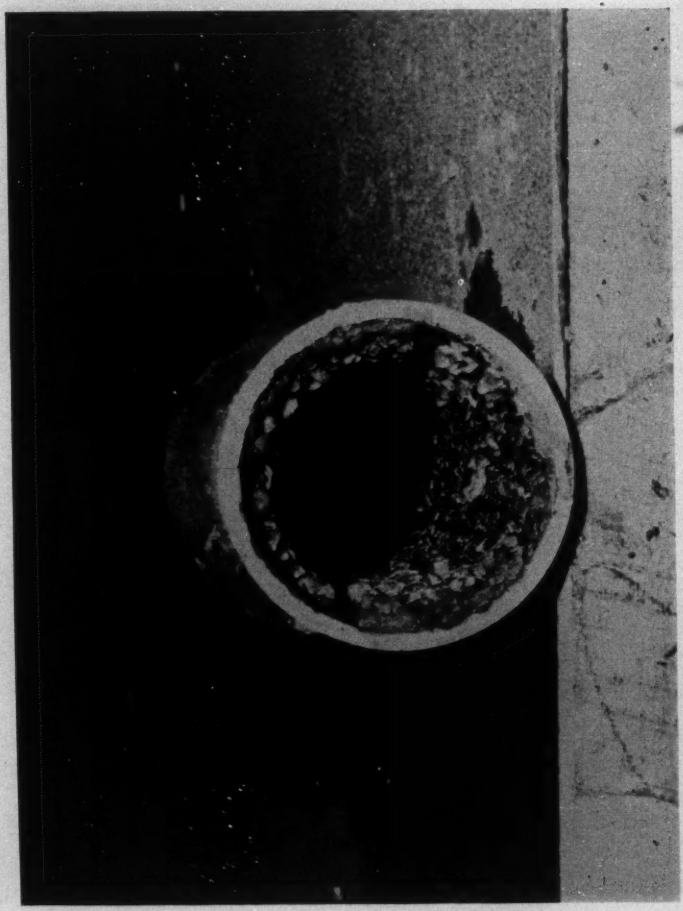

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FIG. 8.

the amount of iron present at a point approximately midway in the clean section of pipe. A leak survey of this section of main resulted in finding a joint leak, where the pipe is in a filled portion of the road approximately eleven feet deep. After repairing the leak, the coefficient dropped to a C value between 121 and 122. This was reasonable, and this coefficient has been maintained to date. The tests to determine the coefficient were made at 2:00 A.M., so as to eliminate as much as possible excessive usage between test points. Some fluctuation in the computed C value is to be expected because of the short test section. A difference of ¼ lb on a gauge reading will make a few points difference. On each date shown on Fig. 9 two tests were made and the results averaged. The average results are shown on this figure. It is well to note that the coefficient of this test section prior to cleaning was 56. Fig. 10 shows a piece of this test section 14 months after cleaning.

Fig. 11 is a composite of three separate flow charts—one showing the pumping rate prior to cleaning the test section of the main; one showing the pumping rate three weeks after cleaning, and the third showing the pumping rate one year after cleaning. It will be noted that the pumping rate before cleaning was approximately 600,000 gpd; immediately after cleaning, approximately 700,000 gpd; and the pumping rate after one year remained at 700,000 gpd, showing that the coefficient of the test section of cleaned pipe has been maintained.

To check the effectiveness of the Calgon treatment in addition to the coefficient test above described, we felt that it was essential to keep a close watch on the iron pick-up and the metaphosphate residual. The pick-up of iron would be an indication of the protection afforded the pipe by the addition of Calgon. If a complete protective coating were laid down on the pipe, there would be no pick-up in iron in this clean section of main.

As previously stated, the pump normally operates from 9:00 A.M. to 2:00 P.M., and for the intervening 19 hours the village is supplied from the standpipe. Samples were collected for iron determination from three points: one at each end of the cleaned section 4,000 ft apart, and one near the standpipe 7,000 ft away from the cleaned section of pipe. These samples were collected just prior to starting the pump.

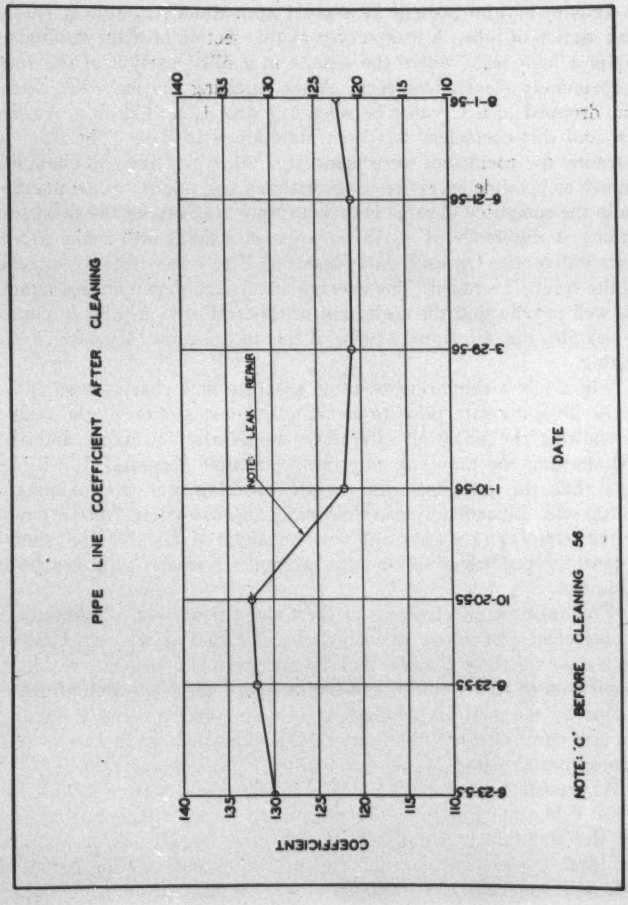
PIPE LINE COEFFICIENT AFTER CLEANING
COEFFICIENT
140
135
130
125
120
115
110
NOTE: LEAK REPAIR
6-1-56
6-21-56
3-29-56
1-10-56
10-20-55
6-23-55
6-23-55
DATE
NOTE: 'C' BEFORE CLEANING 56

FIG. 9.

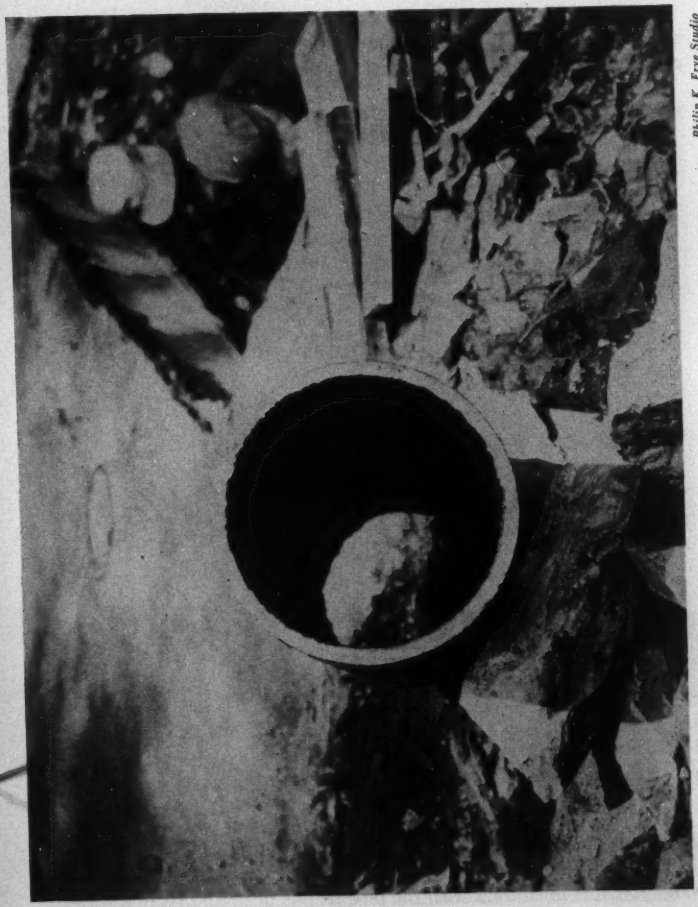

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FIG. 10.

Fig. 12 shows in the upper graph the Calgon feed in parts per million from July 1, 1955, to the middle of August, 1956. The lower graph shows the average iron pick-up per hour in parts per million in

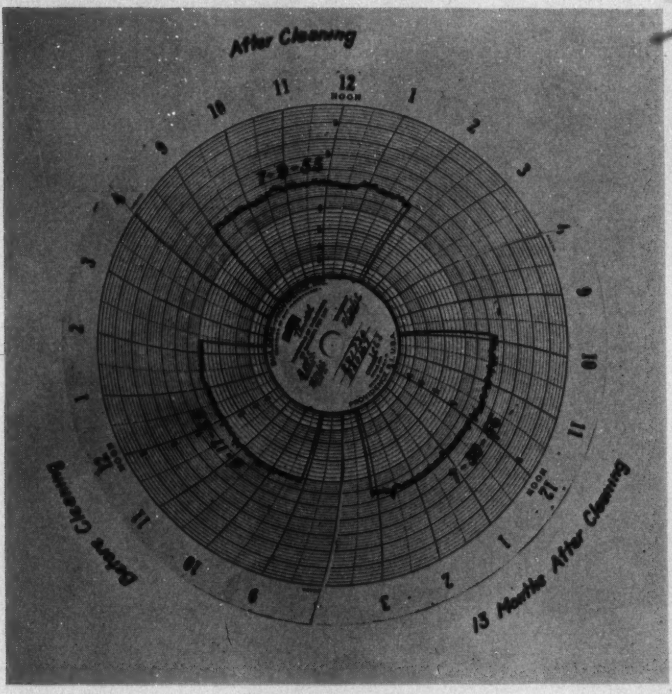

Fig. 11.

the sample collected nearest to the pumping station. As we shall show in Table 2, the iron content in the sample increases the longer the water remains in contact with the pipe in this dead-end section. Therefore, to obtain the amount of iron shown in Fig. 12, the iron content of

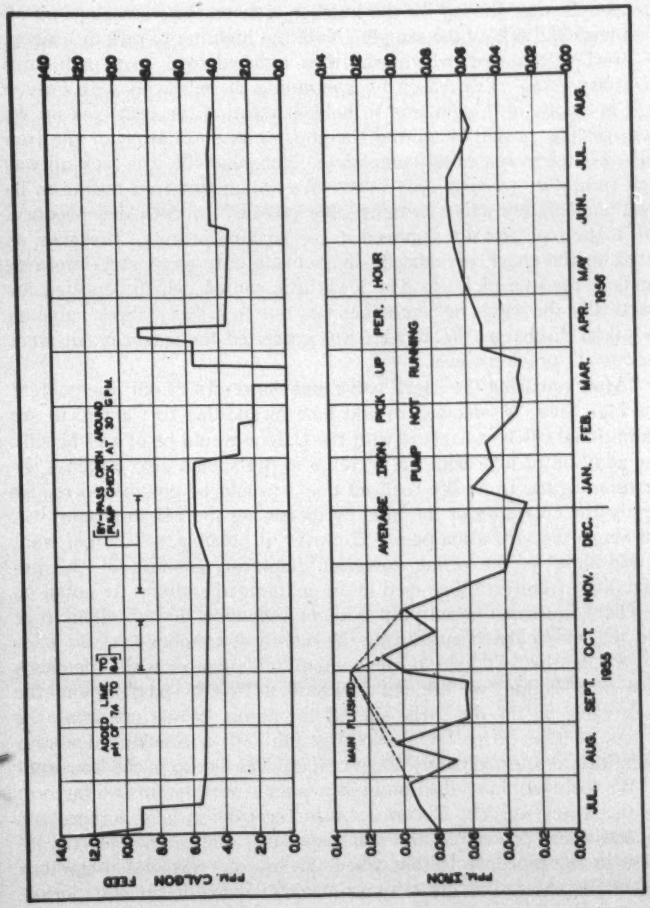
PPM. CALGON FEED
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ADDED LIME TO pH OF 7.4 TO 8.4
BY-PASS OPEN AROUND PUMP CHECK AT 30 G.P.M.
PPM. IRON
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
MAIN FLUSHED
AVERAGE IRON PICK UP PER. HOUR
PUMP NOT RUNNING
JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG.
1955
1956

FIG. 12.

the sample was divided by the number of hours between shutting off the pump and taking the sample. Note the high initial rate of Calgon, as previously stated, which was then reduced to 5 to 6 ppm until February, 1956. The reason for continuing the relatively high Calgon feed in excess of 5 ppm was to hold in solution the iron pick-up we were getting at that time, and thereby prevent oxidation of the iron and consequent red water complaints. Note that the iron pick-up was high from July to early November. We anticipated iron results to be high immediately after cleaning, due possibly to corrosive products left in the pipe and not removed in the flushing process. However, as noted on the chart, periodic flushings made only temporary improvements in the iron pick-up. The lower iron content which persisted for practically the whole of September was due to a leaky check valve on the pump discharge. When this was corrected the iron content went back to its previous level.

After repairing the check valve and the return of our iron content to a high level, we decided to add lime in addition to Calgon, to see if additional calcium to react with the Calgon would be of any benefit. The addition of lime with the increase in pH should also decrease the corrosion of the iron. We realized that it would be possible to reduce greatly the corrosion of the pipe by increasing the pH to around 9.5, just above the saturation point. However, if possible, we did not want to add lime as the prime corrosion inhibitor, because of the unreliability of uniform lime feed in an unattended station. As noted on the chart, we experienced only a slight reduction in iron. This lime feed was only carried out during the month of October.

Noting the reduction in iron content in September while the check valve was leaking, we decided to install a 1-in. by-pass around the check valve on the discharge side of the pump. While operating the by-pass so that, after the pump was shut off, a constant flow was maintained at approximately 30 gpm, there was a drop in the iron pick-up. We feel that this reduction in iron content was due to two factors: (1) the water was not in contact with the iron as long a time, and (2) additional protective film was deposited, due to the velocity increase in the pipe. Note that when the by-pass was closed the iron content increased, but did not, for the remainder of the test period, approach the iron pick-up during the early months.

We have a separate chart (Fig. 13) showing the results from the middle of February, 1956, to the middle of April, 1956. This will be discussed later.

The increase in iron pick-up from May 1, 1956, on we feel was due to the higher water temperature. The decrease in iron pick-up in late July and early August we feel was due to a decrease in water temperature, caused by the cool weather which occurred at that time.

TABLE 2.—IRON PICK-UP OF CLEANED SECTION OF MAIN NEAR PUMPING STATION

Time	pH	Iron (ppm)	Time	pH	Iron (ppm)
	10-24-55			8-13-56	
3:30 P.M.	8.3	Trace	3:30 P.M.	6.9	Trace
5:30		0.1	5:30		0.2
7:30		0.3	7:30		0.3
9:30		0.5	9:30		0.4
11:30	8.0	0.6	11:30	6.9	0.5
	10-25-55			8-14-56	
1:30 A.M.		0.8	1:30 A.M.		0.7
3:30		1.1	3:30		0.8
5:30		1.3	5:30		0.9
7:30	8.1	1.4	7:30	6.9	1.2

NOTE: Each day pump ran from 10:00 A.M. to 3:30 P.M.
Calgon feed 10-24-55—4.3.
Calgon feed 8-13-56—4.5.

Table 2 shows the iron pick-up of the cleaned section of main near the pumping station, starting from the time the pump was shut down at 3:30 P.M. and continuing until 7:30 A.M. One set of samples was collected in October of 1955 and the second set in August, 1956. The pH on October 24-25 reflects the addition of lime during the month of October. It will be noted that in each case shown on this figure the iron pick-up showed an increase at every two-hour interval.

Fig. 13 shows the Calgon feed and iron determination for the period from the middle of February to the middle of April, 1956. The upper graph shows the Calgon feed during this period in parts per million. The lower graph shows the actual iron determination of samples collected near the pump station just prior to starting the pump. The sampling point is the same point from which the samples

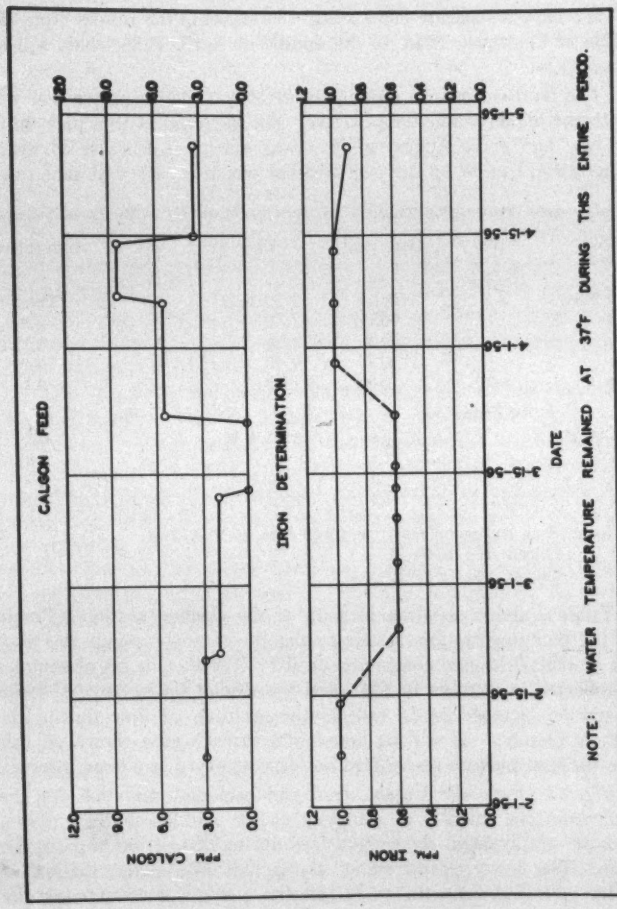
CALGON FEED
PPM CALGON
12.0
9.0
6.0
3.0
0.0
IRON DETERMINATION
PPM IRON
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2-1-56
2-15-56
3-1-56
3-15-56
4-1-56
4-15-56
5-1-56
DATE
NOTE: WATER TEMPERATURE REMAINED AT 37°F DURING THIS ENTIRE PERIOD.

FIG. 13.

were taken as shown on Fig. 12. Note that the water temperature remained at 37°F. during this entire period.

During the middle part of February the Calgon feed was 3 ppm, and the iron determination was 1 ppm. On February 20th the Calgon feed was reduced to 2 ppm and maintained at this rate until March 12th. During this period the iron content of the sample collected just prior to the starting of the pump, after remaining in the main for approximately 19 hours, decreased to 0.6 ppm. Then for a ten-day period no Calgon was added, and the iron remained at 0.6 ppm. We felt that the decrease in the iron content from 1 ppm to 0.6 ppm was caused by the fact that the 2 ppm of Calgon were not sufficient to hold in solution all of the iron coming from the main, and as a result a portion of this iron was oxidizing and precipitating in the main. We feel that the fact that the iron content remained at 0.6 ppm during the ten-day period, when no Calgon was added, was due to the metaphosphate coating on the pipe. Apparently it is possible to discontinue the feed of Calgon for short periods of time without losing all of the benefit from the treatment. We did not want to continue this experiment for a greater length of time without treatment, as eventually we should begin to build up scale or tubercles in the pipeline.

To determine whether or not the drop in iron content was due to oxidation of part of the iron removed from the main with treatment of 2 ppm of Calgon, we decided to add Calgon at the rate of 5.5 ppm. You will note that with this treatment the iron content returned to 1 ppm. We then increased the Calgon feed to 8 ppm, and the next iron determination was found to be 1.0 ppm. Therefore, it was obvious that for conditions existing at that time a treatment of 3 ppm was the minimum for proper control. Later in the year, as the temperature of the water increased and the iron content of the sample increased, we changed the Calgon dose to approximately 4 ppm.

To determine the amount of iron pick-up in the 4,000 ft of cleaned main while the pump was running, samples were taken on the suction side of the pump and at the end of the cleaned main farthest from the pump station. It was necessary to concentrate 1,500-ml samples in order to make this determination. Pumping at the rate of 700,000 gpd, we found the iron pick-up to be 0.023 ppm, which calculates to an iron loss of 0.012 lb per year per foot of pipe. We feel that

even this loss is insignificant, compared to the benefit of maintaining the carrying capacity in the pipe. It is possible that with the new pump installations, which will provide a much longer period of flow, greater protection against corrosion will be obtained, with a corresponding decrease in iron loss.

On Fig. 14 the clear circle shows the amount of metaphosphate added, while the circle with the cross shows the metaphosphate residual on samples taken near the pump station. Again, in all cases shown on this figure the water sample which had remained for approximately 19 hours in the pipeline, under dead-end conditions, was collected just before starting the pump. The difference between the amount of Calgon added and the residual could possibly be considered as the metaphosphate demand, which we assume deposited on the pipe. Note on the samples, immediately after cleaning the main, the high metaphosphate demand, which gradually decreased for a four-months' period after starting treatment. This fact again discloses the importance of a relatively high initial rate of feed immediately after cleaning.

As previously stated, the test section of pipe was purposely chosen so that our experiment would be carried out under the worst possible conditions. We felt that under those conditions the amount of chemical feed would necessarily be higher to maintain our pipeline coefficient than under conditions of continual flow in the pipeline. The comparatively high iron pick-up in this test section disclosed that we were not obtaining 100% protection from the Calgon. Therefore, it was necessary to add more than the normal amount of Calgon feed, to prevent oxidation and red-water complaints. We feel that under conditions of continuous flow it would be possible to decrease the rate of chemical feed and obtain greater protection with the corresponding reduction in iron pick-up.

To determine the effect of Sebago Lake water without special treatment on a piece of cleaned 8-in. pipe taken from the Gorham system, and to determine whether or not we were experiencing any benefit from the treatment, other than the dispersing effect on the iron being removed from the pipe, we ran the following test:

We took a piece of pipe approximately eight feet long, which had been removed from the 8-in. main to insert the cleaner, and through which the cleaner had passed twice, so that this test specimen was

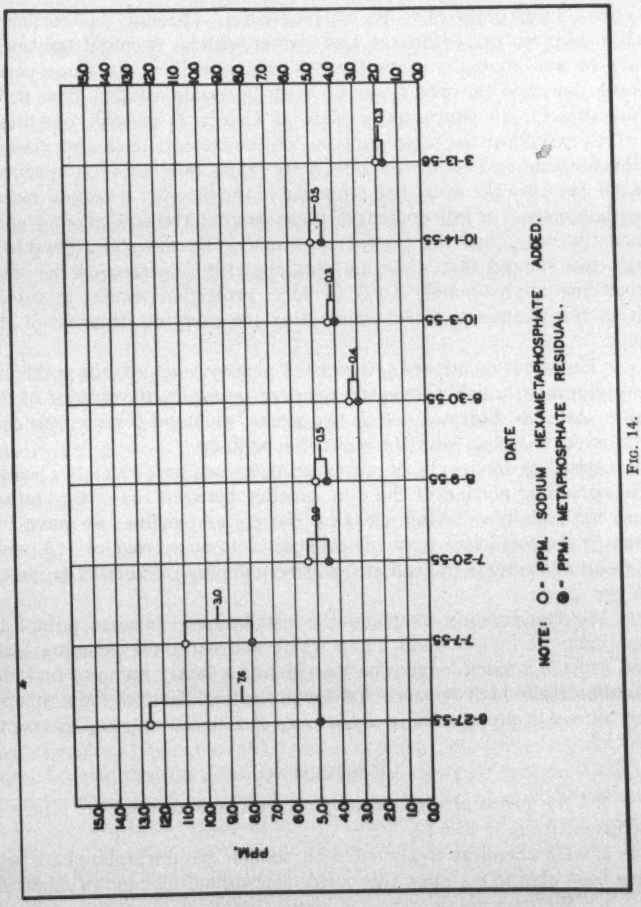
PPM.
DATE
NOTE: O - PPM. SODIUM HEXAMETAPHOSPHATE ADDED.
● - PPM. METAPHOSPHATE RESIDUAL.
8-27-55
7-7-55
7-20-55
8-9-55
8-30-55
10-3-55
10-14-55
3-13-56
7.8
3.0
0.5
0.3
0.5
0.4
0.3
0.5
0.3

FIG. 14.

similar in all respects to the cleaned main. Through this section of 8-in. pipe we passed Sebago Lake water without chemical treatment. Water was allowed to flow through this pipe for a five-hour period each day, and the water was allowed to remain without flow under pressure for 19 hours, to simulate as closely as possible conditions which existed at the sampling point on the cleaned section of main in the distribution system. Samples were taken from this test specimen each day after the water had remained in the pipe for a 19-hour period without flow. The iron content of these samples averaged about 4 ppm, and the water had the typical appearance of red water. Therefore, this test showed that while not obtaining 100% protection, we were receiving approximately 50% to 75% protection against corrosion from the treatment, while maintaining the carrying capacity of the pipe.

The above-mentioned test piece of pipe was capped with mechanical-joint caps, which were easily removed to inspect the interior of the pipe. After as short a period as two weeks, we found considerable corrosion on this pipe, with the start of a build-up.

Based on the results of our experiments, we have recently cleaned the remaining portion of the 8-in. pipeline between the pump station and the standpipe. After cleaning the entire pipeline, we have increased the coefficient from the original 56 to an average of 115, with a resulting decrease in head at the same pumping rate of 100 ft, or 43 lb per sq in.

We have recently completed the installation of two new pumps at the pump station—a small pump which will carry the pumping load and provide a much longer flow period, and a larger pump to provide for abnormally high demands and fire protection. Both of these pumps are automatically controlled by means of telemetering and pressure control.

Conclusion

1. By means of pipe cleaning we were able to raise the pipeline coefficient from 56 to 120.

2. By chemical treatment with sodium hexametaphosphate we have been able to maintain this coefficient without loss for 14 months.

3. We have received no red-water complaints at any time after pipe cleaning.

4. The cost of chemical treatment, as compared to the carrying charges on the cost of either water-main replacement or reinforcement, was small.

5. The labor cost of chemical treatment is minor, as it is necessary for a man to check the pumping station each day, and it requires only a few minutes of his time to prepare the chemical.

6. While complete protection against corrosion was not obtained, we were able to maintain the carrying capacity of the pipeline. We feel that, as time goes on, in all probability there will be some decrease in carrying capacity. If the coefficient of this pipeline does not drop below a value of 100 in ten years, we feel the treatment will be successful.

Suggested Procedure

Whenever possible, Calgon should be used at a feed of 2 to 4 ppm for as long a period as possible, before proceeding with watermain cleaning. This prior feed of Calgon has a tendency to soften the tubercles and is an aid in dispersing the sediment removed from the pipe, so that it does not readily build up and form a plug in front of the pipe cleaner.

Prior to sending the pipe cleaner through the pipe on the last cleaning, one-half pound of Composition Calgon T Glass for each thousand feet of pipe to be cleaned should be inserted behind the cleaner.

After cleaning the pipe it is advisable to start immediately the Calgon treatment as follows:

A. Regular Calgon and Calgon T Glass should be applied in the usual manner in combination of 7 ppm of Calgon T Glass and 8 ppm of regular Calgon. These two chemicals can be mixed together in the same drum and fed through a common pump. However, it must be borne in mind that the combination feed of Calgon and Calgon T Glass should not exceed four times the parts per million of calcium present in the supply. In the event additional calcium is needed, this should be added to the water prior to the addition of Calgon, in the form of either calcium chloride or lime.

B. The above-mentioned combined feed should be continued for a two-week period, after which the Calgon T Glass feed can be elimi-

nated. After the elimination of the Calgon T Glass, the feed will then consist of 8 ppm of regular Calgon. This feed of regular Calgon should continue for a three-week period. After this period, the Calgon feed should be reduced at the rate of 2 ppm each week, until the proper final amount of Calgon feed is reached, which is as follows:

1. The Calgon as a final feed should never be less in parts per million than that required to maintain a metaphosphate residual four times the amount of iron in the water sampled at the end of the clean portion of main.

2. Where, and if, there is continual flow of water in the cleaned mains, the final Calgon treatment normally is around 2 ppm. If the water stands without flowing in any portion of the cleaned main, it will be necessary to test for and determine how much additional Calgon feed is necessary.

The Calgon T Glass material has a zinc base with the property of forming a rapid coat on the interior surface of the pipe. Therefore, in order to hold the initial coefficient obtained after cleaning, it is important to use this material immediately after the cleaning operation, as outlined above.

Acknowledgments

The authors wish to express their appreciation to Mr. Herman Burgi, Jr., Treasurer and General Manager of the Portland Water District, for his helpful cooperation and advice during the experiment, and also to the Trustees of the Portland Water District for their support of the project. We also wish to express our thanks to Mr. J. P. Hennings, Superintendent of the Portland Water District and his efficient crew for their excellent job of cleaning the pipe.

Supplement

Due to the large backlog of material to be published in the Journal of the New England Water Works Association, considerable delay in publication is unavoidable. An additional year's study is now completed and the authors feel that this paper would be of greater interest if a section was added giving results to July, 1957. With this supplement the paper will therefore cover a two-year study

by the Portland Water District on the use of glassy phosphate to maintain pipeline coefficient after main cleaning.

Encouraged by the result of the first year's study we proceeded to clean the remaining 7,000 ft of 8-in. pipeline between the pump station and the standpipe. This main was cleaned in three sections, the work being started on August 14, 1956, and completed on August 17, 1956. The cleaning method was the same as that used in cleaning the first 4,000-ft section.

The dispersing effect of Calgon on the old deposit was quite evident. The material removed from the pipe in the cleaning process did not collect in a pile, as it came out of the main, but ran off with the water discharging from the pipe.

After cleaning the remainder of the 8-in. pipeline to the standpipe, regular Calgon and Calgon Composition T Glass were added in the same proportion and manner as after cleaning the original 4,000-ft section of main near the pump station. The coefficient of this 7,000-ft section of main was 56 prior to cleaning and 112 after cleaning.

Also, on September 15, 1956, two new, automatically operated, electric-driven pumps were put into service as replacement for the old electric-driven pump. The smaller of the two new pumps carries the pumping load and delivers 200 gpm. Thus, the pumping time has been increased from an average of 5 to 6 hours per day to an average of 12 to 14 hours per day. Furthermore, the time between pump operations has been reduced from 19 hours to a maximum of about 7 hours. The decrease of pump capacity, of course, means a decrease in flow velocity.

Fig. 15 is a typical flow chart with the new pump in operation, showing the hours of pumping and the hours between pump operations. As before, a careful record was maintained on iron pick-up, metaphosphate residual, and pipeline coefficient.

Table 3 gives the results of iron and metaphosphate determinations in samples collected from points as shown between the pump station and standpipe. Samples taken through September 14, 1956, were taken just prior to the starting of the pump. This was how we carried on during the first year's study. Samples after September 14, 1956, are under different conditions. Due to the automatic pumping we collected the samples three hours after the pump started.

TABLE 3.—RESULTS OF IRON AND METAPHOSPHATE DETERMINATIONS

Date	Pump operation	Iron in ppm			Calgon feed (ppm)	Metaphosphate residual*	Water temp. (°F.)
		Near pump sta.	4,000 ft from pump sta.	10,500 ft from pump sta.			
8/24/56	P.N.R.(18)	1.2	1.6	1.0	15		68
8/31/56	P.N.R.(18)	1.0	1.6	0.7	12		64
9/14/56	P.N.R.(18)	1.0	1.2	0.6	8		65
9/25/56	P.R.(3)	Trace	0.3	0.7	5	4.0	64
10/18/56	P.R.(3)	Trace	0.3	0.7	5		56
11/29/56	P.R.(3)	Trace	0.1	0.6	3.5	2.5	48
1/10/57	P.R.(3)	Trace	0.1	0.5	3.5		38
2/28/57	P.R.(3)	Trace	0.1	0.5	2.5		36
4/4/57	P.R.(3)	Trace	0.1	0.6	2.5		40
6/5/57	P.R.(3)	Trace	0.05	0.3	2.5		52
6/20/57	P.R.(3)	Trace	0.1	0.25	2.5		66
6/25/57	P.N.R.(7)			0.3	2.5	1.0	70
7/2/57	P.N.R.(7)			0.45	3.5	2.2	70

P.N.R. (18)—Pump off 18 hr when sample taken.
P.R. (3)—Pump running 3 hr when sample taken.
* Metaphosphate residual on sample collected 10,500 ft from pump station.

Test results have disclosed that, with the longer pumping time, there has been no change in the rate of iron pick-up. Due to the shorter period between pump operations, the maximum iron content is

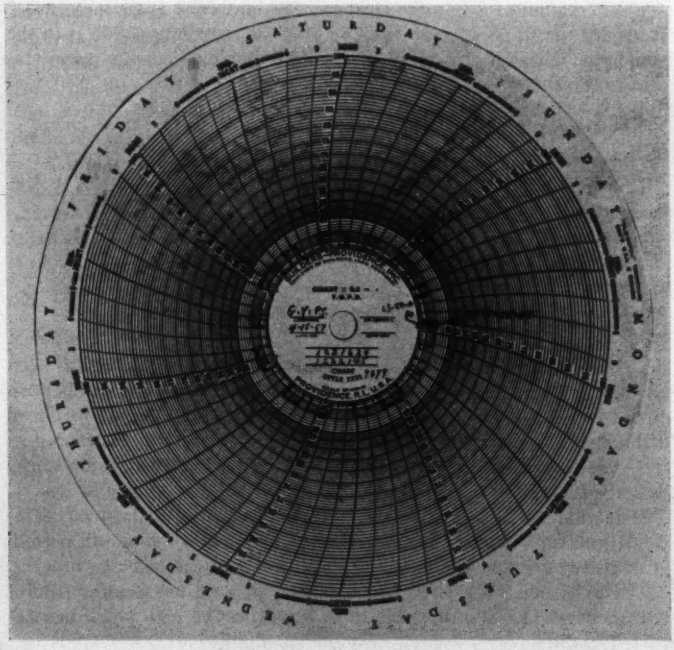

FIG. 15.

decreased, but the rate of iron pick-up per hour in the original cleaned section of pipe, while the pump is not operating, is the same as before the change in pumps. Likewise, while the iron content of the water at the end of the 4,000-ft section of pipe originally cleaned has increased to 0.1 ppm with the 200-gpm pump in operation, the iron pick-

up still calculates to about 0.023 ppm and the iron loss per year per foot of pipe remains at 0.012 lb.

Table 4 gives the results of coefficient tests made on various sections of the 11,000 ft of 8-in cleaned pipe. Section No. 1 is the original 4,000-ft section of 8-in. pipe cleaned. Section No. 2 is the next 3,000 ft toward the standpipe. Section No. 3 is the remaining 4,000 ft to the standpipe. No. 4 is the complete 11,000-ft section from the pump station to the standpipe.

TABLE 4.—RESULTS OF COEFFICIENT TESTS OF CLEANED 8-INCH PIPE

Date	4,000 ft Section No. 1	3,000 ft Section No. 2	4,000 ft Section No. 3	11,000 ft Overall No. 4
8/1/56	121	60*	50*	56*
9/6/56	121	115	110	115
4/4/57	120.5	112.5	103	112
6/21/57	121	116.5	90	110

* Before main cleaning.

It is of interest to note that through June 21, 1957, there has been no loss in coefficient in the first 4,000-ft section of pipe cleaned on June 21, 1955. Thus, the coefficient on this section of pipe has been maintained without loss over a two-year period following cleaning.

The coefficient of Section No. 2 has been maintained without loss over the ten-month period since cleaning.

Section No. 3, closest to the standpipe, shows a drop in coefficient from the original 110 after cleaning to 90 in a ten-month period. It is also noted that the major drop occurred in the last two months.

The overall 11,000 ft of pipe show a drop in ten months from a coefficient of 115 to 110. This drop is due to the loss which has occurred in the 4,000-ft section near the standpipe.

Reference to Fig. 1 will show that practically all of the water pumped passes through the first two sections of cleaned main from the pump station to the grid system, near the center of the village. Then the water fans out in the grid system, with resulting decrease in velocity in the last section of cleaned main to the standpipe. Therefore, there is less chemical passing through the last section of cleaned pipe.

Furthermore, when the pump is not operating, water passes from the standpipe into the system. Then, when the pump operates, the water in the pipeline which came from the standpipe must be repumped into the standpipe, before newly treated water passes through the pipe. Thus the pipeline closest to the tank receives the least amount of fresh chemical.

The warmer the water, the more aggressive it becomes, and therefore the more iron will be removed from the pipe. Also, the warmer the water, the greater will be the reversion of metaphosphate to orthophosphate.

Again refer to Table 3 and note that in June the iron content dropped to 0.3 ppm in the last section, although the temperature increased to 70°F. Also, note that the metaphosphate residual was 1.0 ppm. Apparently there was not sufficient metaphosphate residual to hold all of the iron in solution, and some of the iron was building up on the pipeline, causing a decrease in coefficient on this last section.

This is further substantiated by the fact that when the Calgon feed was increased from 2.5 ppm to 3.5 ppm, the metaphosphate residual at the sampling point near the standpipe increased to 2.2 ppm and the iron content increased to 0.45 ppm. Figure 13 also indicates the result of insufficient Calgon feed.

This section of pipeline closest to the standpipe will be closely watched, to determine the effect of maintaining a metaphosphate residual in excess of four times the iron pick-up. We are hopeful from past results that the decrease in coefficient will be greatly retarded.

This study will continue until definite conclusions are reached. At the present time the authors feel that the conclusions reached at the end of the first year of study still hold. We are well satisfied with the result to date on the first 7,000 ft of pipe cleaned from the pump station and feel that the information gained in this study will enable us better to control the last 4,000-ft section.

We wish to point out that there is no one method of water treatment that will cure all ills everywhere. Therefore, the authors strongly advise a pilot-plant study under actual operating conditions with your water before going to expense on any contemplated change in treatment.

CONTROL OF NEW ENGLAND FLOODS

BY ROBERT J. FLEMING, JR.*

[*Presented November 15, 1956.*]

The water problem in this country is becoming increasingly critical. It has many, many aspects, both qualitative and quantitative. Today in talking about the flood-control problem in New England I am going to discuss one quantitative aspect. You people of the New England Water Works Association are also interested in the quantitative aspect, but primarily are concerned with a qualitative aspect—the purity of the domestic water supply. Flood control involves a quantitative aspect of the water problem, when the quantity gets so tremendous as to cause rampaging floods and serious damage. In this talk I will not always relate the flood-control problem back into the over-all water problem. However, by this omission I mean no disparagement at all to the other aspects of the problem; I think they are all equally important.

Army officers and engineers are often accused of having military and engineer minds. This is supposed to indicate that we are overly preoccupied with history and with materialistic facts and don't have that warm, sympathetic human understanding which so motivates the banker when he is examining a loan application. I will start this discussion of the flood-control problem in New England by going into some past history and reciting some dry facts. Perhaps I had better modify that last statement; the facts will be factual but hardly dry, they will be overly wet. As far as we Americans are concerned, our first experience with floods in New England started shortly after the first settlers arrived, 1635 to be exact. We have fragmentary records of tremendous floods then in the Connecticut and Merrimack River basins; we have very good records of a flood to end all floods in both of these basins in 1683, again in 1692, and with monotonous regularity

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ever since. The first of four great floods in this generation in New England was in 1927. The Merrimack and the Connecticut flooded again in 1936 and in 1938. The lower Connecticut flooded again in 1955, but the Merrimack did not. To my knowledge this is the first time one has acted up without the other one following suit, and this departure from precedent was due entirely to a quirk in the weather pattern.

While the memory of the 1938 flood was fresh in people's minds, there was a public demand for flood control in New England, and the local protective works at Hartford and other cities in the Connecticut Valley were started. Five reservoirs in the upper Connecticut Basin and three in the Merrimack Basin were also started. Then the program ground to a shuddering halt. It remained halted for about ten years and was just beginning to get started again when the August floods hit.

There are probably many reasons for this hiatus of activity. I was not here, and my only knowledge is historical. In my opinion, the two main reasons were an intense and violent opposition by the small minority of people whose interests would be adversely affected, and second, a suspicion in the New England States of the motives of the Federal Government. Whatever the reasons, on August 18 of 1955 the authorized flood-control program in New England was only 20% complete, compared to a national average of about 50%. As a consequence, many New England communities were defenseless, not only against the catastrophe which occurred but even against a routine flood. The point I want to make here, and I emphasize it because I am coming back to this same point later on, is that public opinion for the necessary control works was not sufficiently aroused to overcome the objections.

The pattern of the storm was a big ellipse. Its east and west axis was about 150 miles long and coincided roughly with the Massachusetts and Connecticut border. The north and south axis was about 60 to 75 miles and was roughly up and down the Connecticut River. The heaviest rainfall was 19 in.; the average was 12 to 14. Ordinarily when records in any field of activity are broken, the previous one is shaded a trifle. Dianne was no trifling shader; some of the stream flows were four times anything previously recorded. A good

conservative estimate of damages in New England, Pennsylvania, New Jersey, and New York is about $675 million. New England's share was about $525 million, of which roughly two-thirds was in Connecticut. In Connecticut's Naugatuck River Valley we found gasoline-tank trailers 10 miles from where they broke loose, and one boxcar ended up five miles downstream. It doesn't require much imagination to figure out what happened to buildings and bridges when they were bombarded by boxcars, gasoline-tank trailers, complete lumber yards, and practically everything else that was not nailed down.

I won't go into any further details as to what happened in August, 1955. The losses were tragic. Equally tragic, however, is the fact that much of this loss could have been prevented if, and this is a big IF, the flood-control projects authorized by the Congress years ago had ever been constructed. Had they been constructed, there would still have been a flood and some losses, but those losses, I believe, could have been cut 70%.

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in. runoff control over a substantial part of the drainage basin; second, when a critical situation involves a rather small drainage area, we should increase this control to 10 in. and more; and, third, following the well-known principle that you don't send a boy to do a man's work, New Englanders are in danger of losing their shirts if someone sells them an illusory scheme or a partial solution.

So much for the problem. Now what has been done in the past year? Our first job was to clean up the mess caused by Dianne. We are practically through now, at a total cost in New England of about $27 million, with $18 million in the State of Connecticut and most of the balance in Massachusetts. We still have some clean-up operations and a few problems left in that disaster operation. Most of you have some knowledge of this operation, and I won't discuss it any more.

Spurred by the New England Congressional delegation, the Congress took the uncommon action of voting a supplemental appropriation bill shortly after reconvening in January. This supplemental appropriation gave me a substantial amount of money to start the design and expedite the construction on twelve flood-control projects. This supplemental appropriation in January was followed by the inclusion in the regular fiscal-year appropriation of funds for a greatly expanded program of Federal flood-control works in New England. The total cost of these projects when completed will be about $130 million, and to give you an idea of the size of this program, we will start more projects for the control of floods in New England in this one year than have been started in all the past years since the initiation of the Federal flood-control program.

Soon after the floods, the Congress directed us to make a sweeping review of the New England flood-control plans. This study work has been going on concurrently with the design of those projects already authorized. In cooperation with local and State officials, a tremendous amount of engineering effort has been thrown into this analysis and review. This effort has already resulted in definite proposals for three additional projects in Connecticut, two to protect Torrington, and one to protect Winsted, and a fourth project in Massachusetts, which will add to the protection on the Connecticut River system.

A third prong in the Federal attack on the long-range problem

was modification of flood-control legislation to cut down the time required to initiate projects. The New England flood disaster had a character all its own, unlike any previous big floods in this country, and the Congressional delegations decided that legislation was required, to relax somewhat the very rigid controls Congress had previously imposed on its flood-control program. This culminated in the McCormack-Bush bill, introduced into the House by Congressman McCormack of Massachusetts and in the Senate by Senator Bush of Connecticut. It was passed by both Houses and approved by the President after the passage of the appropriation bill, which did not include funds. So the New England delegations went to work again and got a supplemental appropriation through, specifically designed to finance projects under its provisions. This bill does not give us blanket authority or a blank check to do any work we think necessary. It does, however, greatly decrease the time required to process projects under the monetary limits granted. Incidentally, this bill, sponsored by a Democrat and a Republican, is an excellent illustration that floods are nonpartisan.

There are other aspects of this flood-control problem which are even more important than the engineering factors. These are political aspects, and I use the word "political" in the broader sense, meaning the interplay of the factors involved in any government operation. The engineering and economic factors determine what should be done; the political factors determine what will be done. The key factor in any political action in a democracy is public opinion. If it is favorable, you go ahead; if it is not favorable, action stops. As of right now, public opinion towards flood-control projects in Southern New England is favorable, but before the August floods it was not aroused, and that is the basic reason why many parts of New England which could have been protected were completely defenseless. But a year after the tremendous disaster, I detect rumblings which may develop again into opposition. We in the Army have a slang term, "smoke screen", which we apply to a lot of fuss and fury that obscures the basic issue. These flood-control smoke screens are (1) reforestation and watershed treatment, (2) multi-purpose reservoirs, and (3) small dams vs. large dams. The basic factor which makes each a smoke screen is the topography, or the physical characteristics, of New Eng-

land. These physical characteristics make the New England streams vulnerable to flash floods of terrific intensity and, secondly, have dictated a pattern of settlement and development in the river valleys that imposes very high real-estate costs on any protective project. The first of these smoke screens is the reforestation and watershed-treatment issue. I think these are extremely valuable in the over-all problem of water conservation and development in this country. Anybody who does not agree with their value is somewhat stupid, but I must violently disagree with their over-enthusiastic partisans who claim that they are the answer to the flood-control problem. Reforestation and watershed treatment are of tremendous value in reducing erosion, in water conservation, and in reducing pollution. Because of the vulnerability of New England streams, however, to flash floods, these measures have little value here in controlling a major flood. An impartial analysis shows that if there were perfect watershed treatment on New England streams, this would not reduce major flood heights more than 5%. Concerning reforestation as an answer to flood control, New England is now well forested, and I don't think any large-scale program of reforestation is practical. I also doubt the effectiveness of any reforestation program in reducing major floods. In 1635, 1683 and 1692 New England was practically a virgin wilderness, yet there were tremendous floods, and the Indians and Colonists alike either took to the hills or spent some uncomfortable days roosting in the tops of trees.

The second smoke screen is that of multi-purpose reservoirs. Many big projects have been built in other parts of the country which combine flood control, power, conservation, and other uses in the same reservoir. These are the so-called multi-purpose reservoirs. They are essentially compromises, because the requirements for flood control on one hand, and the requirements for power, conservation, and domestic water storage on the other hand are diametrically opposed. The flood control boys are happy only when their reservoir is empty, and the power and conservation people are happy only when theirs is full. The top and the most valuable part of a multi-purpose reservoir must always be left empty for flood-control use. No one has yet figured out a way of jacking the power pool or the conservation pool up from the bottom of the reservoir and leaving the flood-control part

empty down there. Multi-purpose reservoirs are practical solutions for flood control only if they can be built big enough to leave a substantial portion of the reservoir empty. In New England it is difficult to find sites for reservoirs large enough physically to combine satisfactorily those purposes. It might be possible to build a larger number of smaller multi-purpose reservoirs, but I am inclined to doubt if this would be economical.

The third smoke screen is that of large dams vs. small dams. My answer to that is that we are building small dams. Compared to the large structures in the mid and far West, these proposed New England projects are fish ponds. All the remaining authorized New England projects could be built for less than the cost of one project on the Columbia River. For example, the Thomaston Reservoir on Connecticut's Naugatuck River would have a reservoir area of about 900 acres when full. The Fort Peck reservoir on the Missouri River has an area one-third the State of Rhode Island, and the water stored in that reservoir would cover the entire State of Connecticut six feet deep. If you used Thomaston as a bucket to bail out Fort Peck, you would be mighty tired. You would have to bail almost 500 times. The New England projects are not large projects, and smaller ones yet would be much more expensive.

The 1955 New England floods gave an emphatic and disastrous sermon to the people of New England. I want to emphasize some lessons from that sermon. The first lesson involves public opinion, which I said earlier was the factor which controlled the eventual construction of an authorized project. There is always opposition to any proposed public project, not all of it constructive. There is a sizeable group of people, the "let's don't do nothing boys", to whom unlimited debate has become an end in itself and not a means to progress. There is also an intense and highly vocal opposition from the small minority of people whose interests may be adversely affected. It is impossible to build any public project for the general benefit without some adverse effect on a few. In Federal flood-control legislation, the Congress has decided that no project will be built unless the State in which located has concurred. In Southern New England an aroused public opinion has overcome the opposition which previously blocked this State concurrence. The lesson that I want to draw is that I

believe the "let's don't do nothing boys" and the small local and highly vocal minorities have been given far too much weight.

The second lesson is the answer to a question which I am asked continuously: "When and how big will be the next flood?" In answering it, I always tell the story of Mr. Philip Shutler, a Vermonter, who has been mixed up in water conservation in New England for years and who is now executive director of the Connecticut River Flood Control Commission. He and I were speakers at a meeting in Hartford a year ago in July, which we and some others had drummed up to focus attention on the unsolved flood-control problem. At that meeting somebody asked Mr. Shutler the same question, and his reply was that we were 17 years away from the last flood and that to him merely meant we were 17 years closer to the next one. I was at a meeting during the first week of October last year in Connecticut when somebody asked me the same question. I answered that we were two months closer to the next one, and a week later Connecticut and Massachusetts were clobbered by the October flood. Answering that question is a lead-pipe cinch, almost like shooting fish in a barrel. It has now been one year since the last big flood in New England, and to my simple mind that only means we are one year closer to the next one.

HISTORY AND OPERATING PRINCIPLES OF THE MAGNETIC FLOW METER

BY RUSSELL H. BABCOCK*

[*Read December 20, 1956.*]

Since the earliest days of water-works practice, there has been a continuing effort to improve existing methods of measurement and to develop new instruments for more accurate appraisal of system variables. The latest development in this search for better measurement is the magnetic flow meter. Because flow is one of the principal variables on which the operation of installations depends, consideration of this new device is both timely and applicable.

The principle of operation of the magnetic flow meter is essentially the principle of electromagnetic induction first proposed by physicist Michael Faraday in the early part of the nineteenth century.

In 1839, Faraday tried to measure the flow of the Thames River by applying his theory of electromagnetic induction. He placed two copper wires in the Thames River and, using the earth's magnetic field, attempted to measure the flow of river water. Because his voltmeter was somewhat less sensitive than he anticipated, the attempt did not succeed. Faraday reported in his notes as follows: "I constantly obtained deflections of the galvanometer but they were very irregular and were in succession referred to other causes than that sought for. The different condition of the water as to purity on the two sides of the river; the difference in temperature; slight differences in the plates, in the solder used, in the more or less perfect contact made by twisting or otherwise; all produced effects in turn; and though I experimented on the water passing through the middle arches only; used platinum plates instead of copper; and took every other precaution, I could not after three days obtain any satisfactory results."

No further work of major importance was done on electro-

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magnetic metering of flow until Smith and Sleppian developed their magnetic ship's log, securing a patent on the device in 1917. At the present time, the United States Navy is engaged in building a ship's log based upon this principle.

Since that time, an impressive number of separate investigations have been carried out, but in no instance was complete success achieved until the development of the Foxboro Magnetic Flow Meter. Earlier attempts failed to solve the problem of providing a high degree of accuracy, a wide range of meter sizes, and insensitivity to such effects as temperature and conductivity.

To understand how the magnetic flow meter meets the requirements of flow measurement, it is only necessary to review Faraday's law of electromagnetic induction. In general, this law states that if a magnetic field is generated in one direction and a conductor is moved at right angles to the field, a voltage will be generated which is directly proportional to the speed of the conductor and the strength of the field. In terms of instrument design, Figure 1 shows that if an electromagnet generates a magnetic field of constant strength at right angles through a non-magnetic flow tube and a conductive liquid is passed through the tube, a voltage will be generated which is directly proportional to the rate of flow of the liquid. In direct contact with the liquid are two electrodes set into the tube diametrically opposite each other and insulated from the tube. To avoid shorting out the voltage, the tube is lined with an insulating material. The voltage signal from these electrodes is recorded in desired units of flow on an AC millivolt-meter of special design (Fig. 2). The equation of the magnetic flow meter is as follows:

$$E = K\frac{VHd}{A}, \text{ where}$$

E= generated EMF, measured at the electrodes;
K= a constant for units of measurement;
V= volume of liquid per unit of time;
H= field strength between electrodes;
d= distance between electrodes;
A= cross-sectional area inside pipe.

This equation shows that the millivoltage output is equal to the product of the constant for the unit of measurement, the volume per

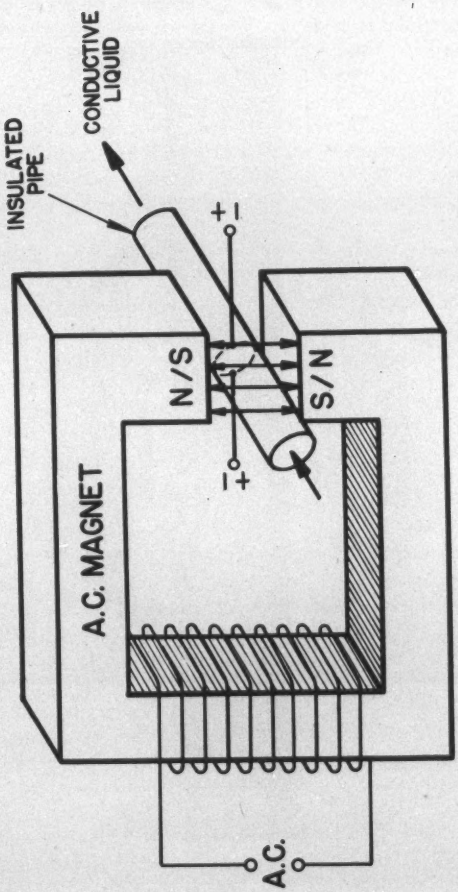


FIG. 1.

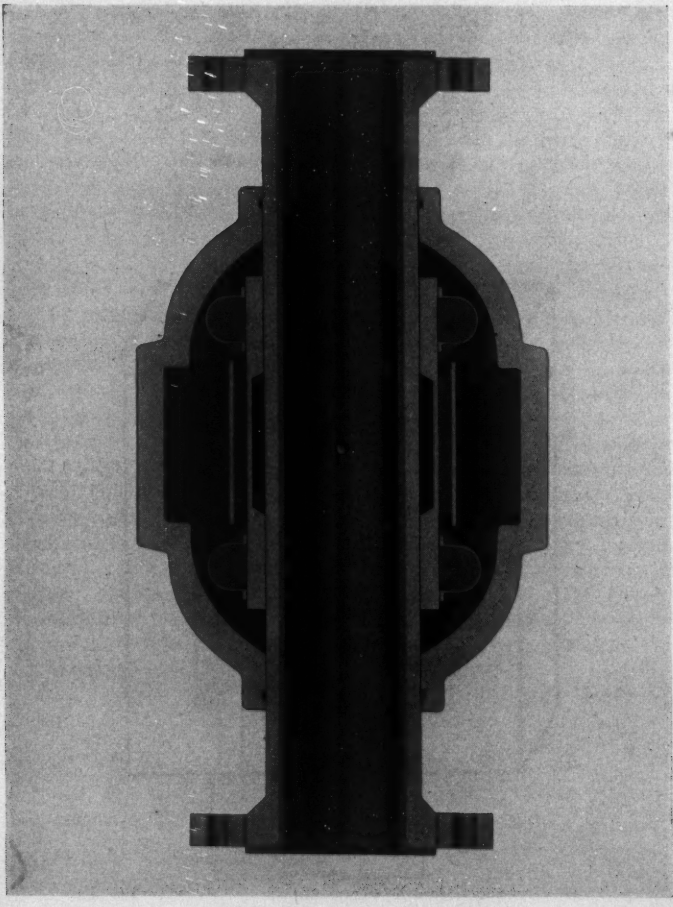


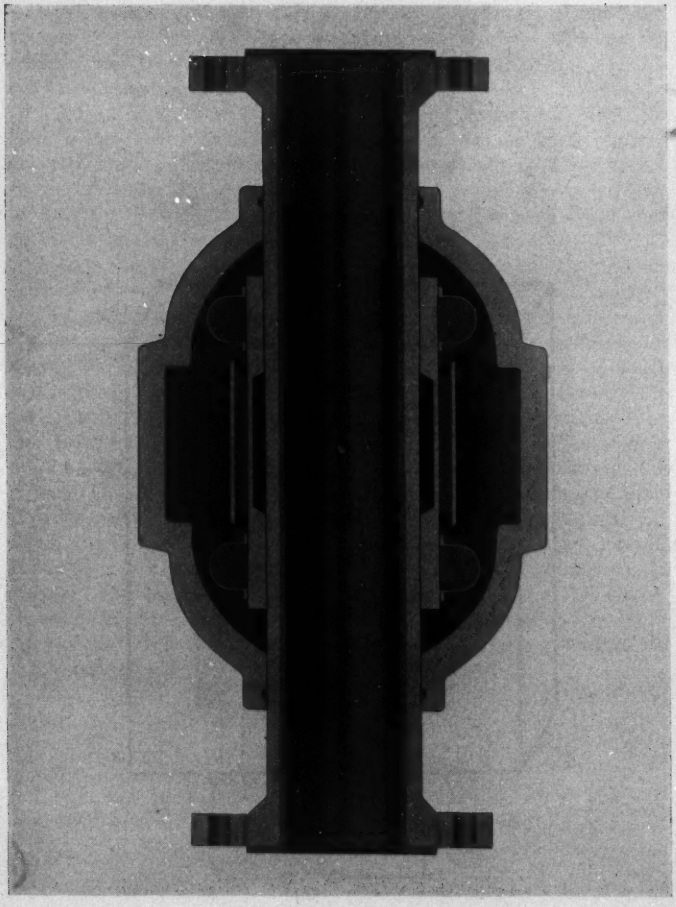
FIG. 2. CROSS-SECTION DRAWING OF MAGNETIC FLOW TRANSMITTER (*The Foxboro Co.*)

unit of time, the field strength, and the distance between electrodes, divided by the cross-sectional area of the pipe. This equation is entirely linear and includes no square-root function to complicate recording.

In evaluating the adaptability of the meter to typical water distribution and treatment applications, the question of turbulence or variation of the flow profile naturally arises. The magnetic flow-meter reading is the average of the incremental velocities occurring within the pipe section between the two electrodes. Weigh-tank tests have proved that there is no appreciable change in measurement accuracy between turbulent and laminar flow. The results of a test conducted by the Alden Hydraulic Laboratory on an 8-in. magnetic flow meter are shown in Figure 3. The deviations from the normal calibration curve occurred when a pipe elbow was installed directly upstream and when a swirl was artificially induced. In neither instance was any appreciable error observed.

Only when a conductor moves through a magnetic field will a measurable EMF be generated across the electrodes. Therefore, in electromagnetic metering the fluid to be measured must be conductive. What constitutes a conductive fluid for purposes of electromagnetic flow measurement? The fluids encountered in water-works applications normally have a conductivity greater than 100 micromhos. This is far above the minimum conductivity of 50 micromhos required for an 8-in. magnetic flow meter with 300 ft of lead wire between transmitter and receiver. It has been demonstrated that at values below 50 micromhos, the only undesirable effect is a wandering zero when there is no flow in the line. When flow resumes the meter reads accurately.

Since the magnetic flow meter is not subject to the effects of upstream disturbances, it is possible to predict in advance of installation what the accuracy of the meter will be. The magnetic flow meter, including the transmitter and the recorder, has an over-all accuracy of 1% of full scale. It is not necessary to add a safety factor to allow for possible errors from an improperly installed primary device, as is done in calculating inferential meter accuracies. Regardless of the manner of installation, the accuracy of the magnetic meter remains unchanged at 1% of full scale.



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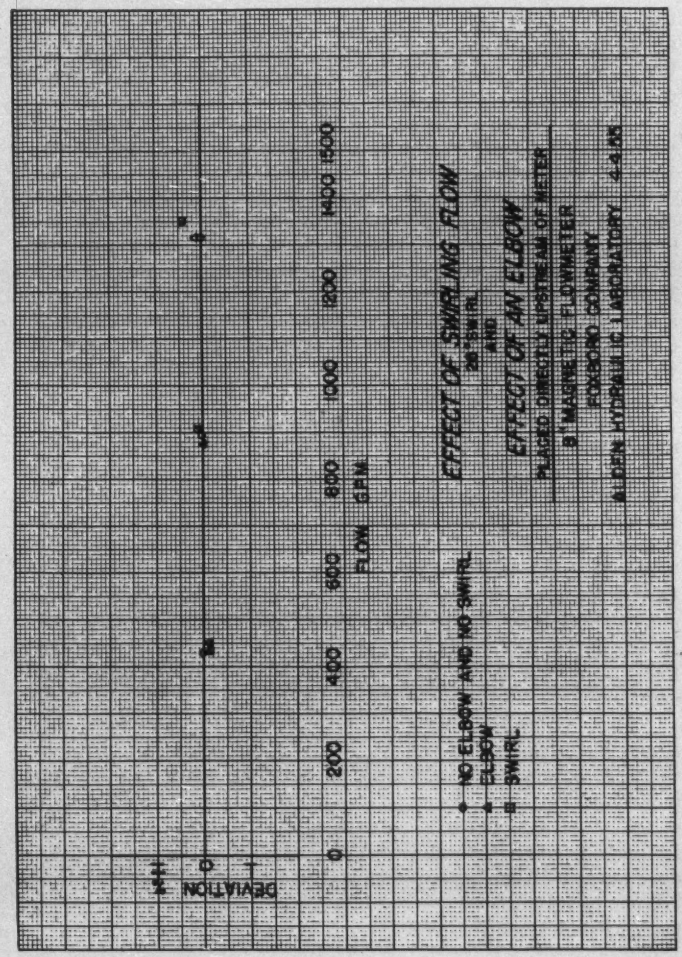
EFFECT OF SWIRLING FLOW
AND
EFFECT OF AN ELBOW
PLACED DIRECTLY UPSTREAM OF METER
8" MAGNETIC FLOWMETER
FOXBORO COMPANY
ALDEN HYDRAULIC LABORATORY
NO ELBOW AND NO SWIRL
ELBOW
SWIRL
DEVIATION
FLOW G.P.M.
0
200
400
600
800
1000
1200
1400
1500

FIG. 3.

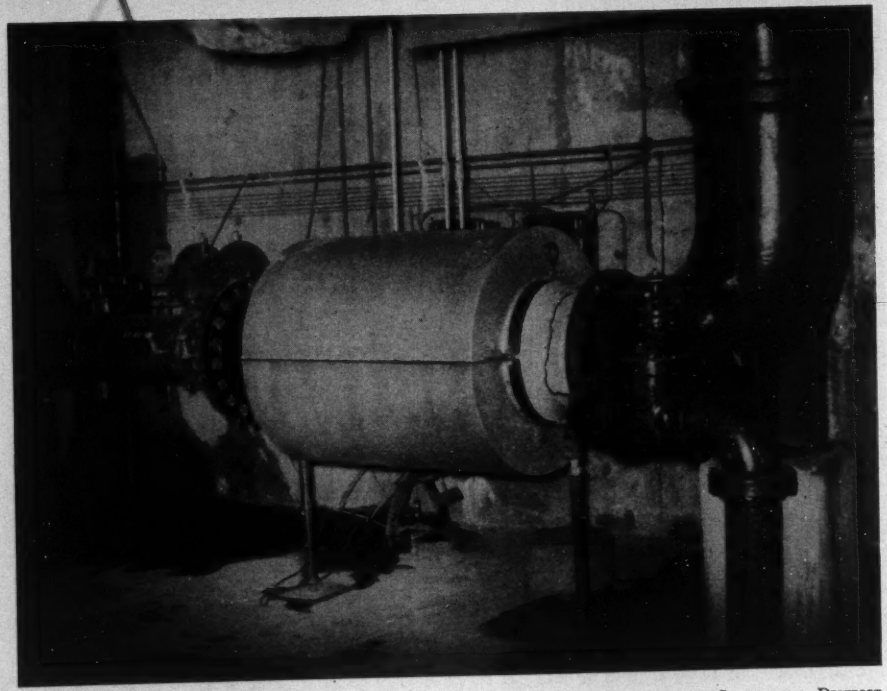

FIG. 4. TWENTY-INCH MAGNETIC FLOW TRANSMITTER, TRANSITE TUBE, INSTALLED AT SOUTHWEST DISTRICT FILTRATION PLANT, CHICAGO, ILL. (*The Foxboro Co.*)

To water-works engineers, the magnetic flow meter has certain obvious application advantages. It adds no more loss of head to a hydraulic system than a straight pipe of the same length and size. Since it does not require a straight meter run, installation costs are apt to be much less than for other primary devices.

A 20-in. magnetic flow meter has been in service at the Chicago Southwest District Filtration Plant since the summer of 1956. John Baylis is preparing an article on the installation to appear in "Pure Water", a publication of the Chicago Water Department. In it, he expresses satisfaction with the meter and reports that its high degree of sensitivity has enabled him to observe effects of line noise, produced by the recovery cone of a Venturi tube downstream (Figure 4). In this instance, the meter is installed on the end of an elbow and directly upsteam of a hydraulic rate-of-flow controller.

A number of meter installations have been made in the process industries—particularly, in the field of pulp and paper manufacture. The meter has obvious advantages for handling fluids containing high percentages of solids, because there is no need for purge systems, and there are no pockets or crevices in the flow tube where material can accumulate.

The sewage-treatment field is also starting to use the magnetic flow meter in great numbers. Many engineers consider it very nearly the ideal metering device for sludges.

In summary, the magnetic flow meter is based on principles as old as the earliest laws of electricity. Its application to flow-measuring problems that have traditionally plagued water-works engineers will undoubtedly lead to more efficient plant operation and greater design flexibility.

USE OF THE MAGNETIC FLOW METER AT MEDFIELD, MASSACHUSETTS

BY EDWIN B. COBB*

[*Read December 20, 1956.*]

The first use of a magnetic meter to measure two-way flow of water in a public water system was, as far as we can learn, at Medfield, Mass. A public water supply is not generally considered a good place to experiment with newly developed devices, but in this case the convenience and saving in cost obtained by use of such a meter justified its selection.

Medfield is a predominantly residential town, located about 17 miles southwesterly from downtown Boston. The 1950 population of the town was reported as 4,549, including 2,136 inmates of the Medfield State Hospital. The 1955 State census gave the town a population of 5,293.

Prior to 1956 and since 1932, the town purchased water under contract from the Medfield State Hospital. In 1953 the supply to the State Hospital was found to be inadequate to meet the future requirements of both the town and the hospital, and an additional source of supply was considered. The hospital authorities decided that an additional supply of 1.0-mgd capacity, estimated to cost $90,000, would be required and proposed to pass this entire cost on to the town through increased water rates. The proposed increased rates would have made the cost of the water delivered at service pressure about $350 per mil gal. The town officials considered this a high price to pay for water and decided to investigate the possibility of an independent supply for the town.

The writer's firm of Metcalf & Eddy was engaged to study the situation and to make a recommendation as to the most economical solution. After a careful investigation of the problem, the construction of a ground-water supply by the town was recommended. It was estimated that amortization of the cost of developing the supply, plus

* Partner, Metcalf & Eddy, Statler Bldg., Boston 16, Mass.

the cost of pumping the water, would be equal to around $165 per mil gal, or only about half the proposed cost of water purchased from the hospital. This recommendation was adopted, and a gravel-packed well with pumping station and force main was constructed on Route 109 near the Charles River.

Under usual procedure, the town would have also constructed its own standpipe, to provide a supply to supplement the pumpage from the well during peak demands on the system. The existing standpipe at the State Hospital, however, is of generous proportions, and the hospital authorities were quite willing for the town to continue to share its use with them. In addition, the continued interconnection of the systems would give each an auxiliary source of water for use in an emergency. Successful operation of the arrangement, however, required the provision of a meter at the point of interconnection, which could measure the flow in two directions.

The general arrangement of the water systems of the town and of the Medfield State Hospital is shown in Fig. 1. The State Hospital obtains its supply from a well field on the southerly side of the Woonsocket Branch of the New Haven Railroad, about 1,500 ft easterly of Harding Street. This supply consists of 63 2-1/2-in. tubular wells, together with a pumping station equipped with two centrifugal pumps, each rated at 900 gpm. Water is pumped through a 12-in. main as far as Harding Street, where it is discharged into a 16-in. main which runs northwesterly to a standpipe at the hospital and southeasterly to the center of Medfield. A meter vault, now equipped with a magnetic meter, is provided in the 16-in. main leading to the town.

The new town well has a rated capacity of about 290 gpm and discharges to an 8-in. main in Main Street (Route 109), which connects with the above 16-in. main at the center of the town. A Dall tube at the pumping station provides a means of measuring the pumpage from the well.

To quote from the Metcalf & Eddy report submitted in December, 1953, the water consumption by the town for the 12-month period ending October 31, 1953, was as follows:

Yearly daily average	145,000 gpd
Maximum monthly daily average	208,000 gpd
Maximum day	318,000 gpd

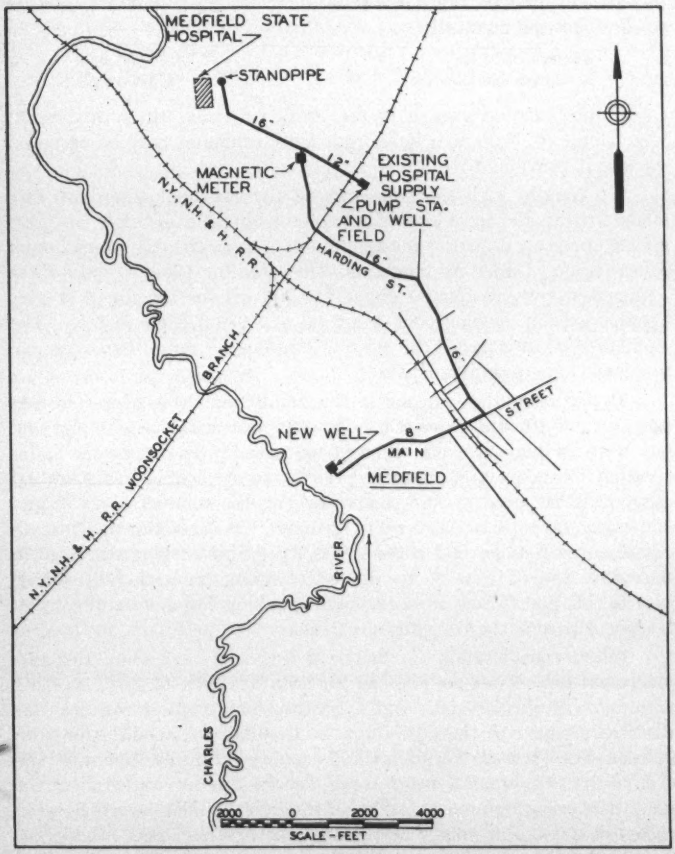

FIG. 1. WATER SYSTEM OF TOWN OF MEDFIELD AND MEDFIELD STATE HOSPITAL.

It was estimated that by 1980 the water consumption would increase to the following amounts:

Average daily use	189,000 gpd
Maximum one-day use	378,000 gpd

Unprecedented growth in the town, occurring since this report was submitted, leads to a belief that these estimates may be exceeded somewhat previous to 1980.

To comply with the standards of the National Board of Fire Underwriters, the town should be able to obtain a fire flow of 2,000 gpm at the central district for a period of 8 hr on the day of maximum consumption. Under the conditions estimated for 1980, to meet these requirements would require about 960,000 gal for the fire flow plus 126,000 gal for consumption, or a total of 1,086,000 gal in 8 hr. The 1,680,000-gal capacity of the existing standpipe is more than adequate to supply this quantity of water.

In proposing the joint use of the standpipe, it was suggested that each system attempt to match its consumption with its pumping and any over- or under-run be adjusted periodically by decreasing or increasing the respective pumping periods, as applicable. Such an arrangement has been in force since early in the summer of 1956 and appears to be working very well. Recently, the Medfield superintendent reported that he had about 1,000,000 gal of surplus pumpage in the bank, and in view of his limited pumping capacity (290 gpm), he felt this placed him in a favorable position for maintaining good relationship with the hospital authorities.

Initial consideration for metering was a system using two displacement-type water meters, one for each direction of flow, together with suitable check valves and bypasses. The greatest concern was the measurement of the flow from the hospital system into the town system. For reasons of economy and accuracy of measurement, it was desired to use as small a meter as possible for this service, while at the same time avoiding undue restriction through the meter when flows in excess of 2,000 gpm might be required for fighting fires. Studies indicated that the existing meter vault was too small to accommodate suitable displacement-type meters, and new vaults would be necessary together with some awkward connections to the 16-in. main. A further

drawback would be the inconvenience of opening and entering a vault in the street at frequent intervals to read the meters of this type. The estimated cost of such an installation was about $9,300.

About this time, the writer became acquainted with the magnetic meter, as manufactured by The Foxboro Co. Upon investigation, it was learned that such a meter could also be made to measure flow in both directions, through the provision of suitable relays in the secondary instrument. A 6-in. meter was found to be of proper size, and this meter, having a smooth flow tube of 6-in. diameter, would offer but little resistance to high rates of flow. Most helpful of all, it was found that this meter could, with but minor modifications in piping and with no interruption of service to the town, be installed in the existing meter vault. Being of the electrical type, the secondary instrument was readily mounted on the roadside in a weatherproof housing, and in this way the necessity of frequent opening of the meter vault was eliminated. The cost of the installation, exclusive of engineering, was $5,132.

The meter was specified to be of 6-in. size, rated for 2,000 gpm in one direction and 500 gpm in the other. The secondary instrument has two totalizing dial counters, reading directly in gallons, one to record the total flow in each direction. Ordinary, 110-volt, single-phase electric current was sufficient to furnish power to the unit. The meter and appurtenances were furnished and installed under contract by R. H. White Construction Co., Inc., of Auburn, Mass. A view of the meter as installed in the vault is shown in Fig. 2. The secondary instrument mounting and housing at roadside are shown in Fig. 3. The slight amount of heat generated by the power dissipated in the meter appears to protect it from dampness.

The standard-type secondary instrument furnished by the manufacturer includes a mounting for a recording chart. Since a special instrument which omitted the chart would have been more expensive, a standard-type unit was accepted. As a matter of interest, charts have been placed on the recorder from time to time, to observe the pattern of flow variation. A typical chart, which recorded the flow from 8 a.m., October 4, to 8 a.m., October 5, 1956, is shown in Fig. 4.

Had the recorder been specified with the equipment, the manufacturer stated that a different type of unit with surge dampeners and

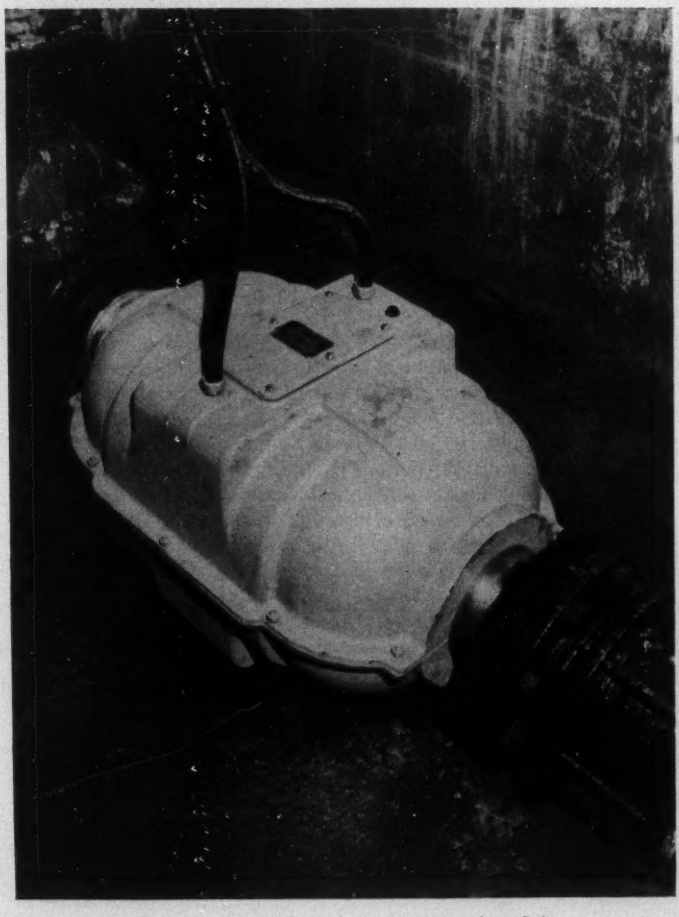

FIG. 2. MAGNETIC METER IN VAULT (*The Foxboro Co.*)

FIG. 3. SECONDARY INSTRUMENT MOUNTING (*The Foxboro Co.*)

other devices would have been provided, which would have given a much more readable record. In spite of their shortcomings however, considerable information about consumption characteristics of the town system can be obtained, when desired, from occasional charts on the present recorder.

Since the meter is rated differently for each direction of flow,

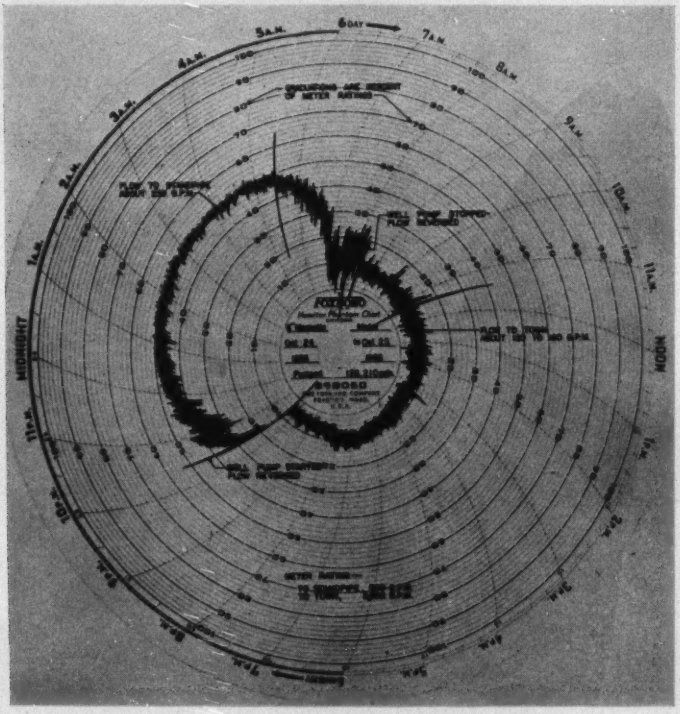

FIG. 4. TYPICAL CHART FROM MAGNETIC METER.

the chart graduations read in percentage of rated capacity. Thus, the portion of the record along the 50 graduation would be interpreted to be 50% of 500 gpm, or 250 gpm, and indicates that this flow is going into the hospital system. The difference between this reading and the 290-gpm discharge of the well pump, or 40 gpm, indicates the rate of consumption by the town.

Similarly, the portion of the curve along the 6 graduation indicates that with the well pump shut off, 6% of 2,000 gpm, or about 120 gpm, was flowing from the hospital system into the town system.

To determine when to change scales, the long, curved lines normal to the graduations are picked out. When there is a reversal of flow, the indicator drops to zero and then goes to the other range. This is best illustrated by the line at 10:30 p.m. Just previous to this time, the well pump was not in operation and the flow was to the town. At 10:30 the pump was started and the direction of flow reversed. The meter continued to indicate in this range until about 8:30 next morning, when the pump was shut off. Between 5:30 and 7 a.m., the consumption by the town increased to a point where it was taking nearly the entire pumpage from the well. Between 7 and 8 a.m., the rate of consumption exceeded the pumpage from time to time, and there were several reversals of flow. In the area of rapid reversal of flow, the chart is not of too great value, since it is almost impossible to determine which scale to read. After the pump was shut down at 8:30, the flow settled down to one direction and varied between 120 and 220 gpm, with a peak flow to town of about 240 gpm around 7 p.m.

The records on the totalizer are reported to be quite precise, since the meter is very sensitive to small flows and the reversing relays in the secondary instrument are capable of operating at relatively high speeds.

Because the magnetic meter is a fairly new development, together with the possibility of failure in the electrical appurtenances, the manufacturer has been placed under contract to inspect and test the meter quarterly for a period of five years. A simple electrical measurement permits the inspector to check the adjustment of the secondary instrument precisely. The meter was placed in service May 3, 1956, and to date only one failure of the meter has been

reported. This failure was apparently due to the failure of a relay. The relay has been redesigned and replaced by the manufacturer.

The use of the magnetic meter at Medfield represents a special application to which it appears well suited. Its installation afforded definite savings in cost over a more conventional arrangement, and permits more convenient access for reading and checking. Experience to date indicates that it is as reliable as other commercial types of flow meters of similar capacity.

SYNTHETIC DETERGENTS AND PUBLIC WATER SUPPLIES

BY CLAIR N. SAWYER* AND DEVERE W. RYCKMAN**

[*Presented at Chemists' Round Table, Jan. 17, 1957.*]

New England cities are extremely fortunate in having water supplies which are relatively free from contamination by human wastes. Nevertheless, there are a few communities that are forced to use supplies of less than pristine purity. In the future, it is reasonable to assume that many cities will need to augment their supplies from less desirable sources, and that present supplies will become more and more subject to contamination by human wastes, as population pressures increase. It behooves us, therefore, to keep abreast of the changes occurring in the character of human wastes and the effect such changes may have upon the product we produce.

During the past 10 years a great change has occurred in the character of cleansing materials used by the housewife. At the present time over 50% of all detergents sold for household purposes are of the so-called synthetic type (Figure 1). Acceptance of these new materials has been rapid in hard-water areas, and they are gaining favor even in soft-water areas, like New England.

From time to time reports have appeared in the water-works literature blaming contamination by synthetic detergents for certain difficulties in water-works practice. These difficulties have usually been of three categories: (1) serious frothing or foaming where aeration was practiced, (2) interference with coagulation, and (3) taste and odor problems.

Recent studies by investigators of the U.S.P.H.S. at Cincinnati (1) and in our laboratory (2) have demonstrated that the organic surfactants, in themselves, do not interfere with chemical coagulation, but the complex phosphates, usually sodium tripolyphosphate, which are used as builders in all heavy-duty synthetic detergents increase the coagulant requirements considerably. With heavier dosages of coagulant, good results can be obtained, but only a small fraction

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** Civil Engineering Dept., Washington University, St. Louis, Mo.

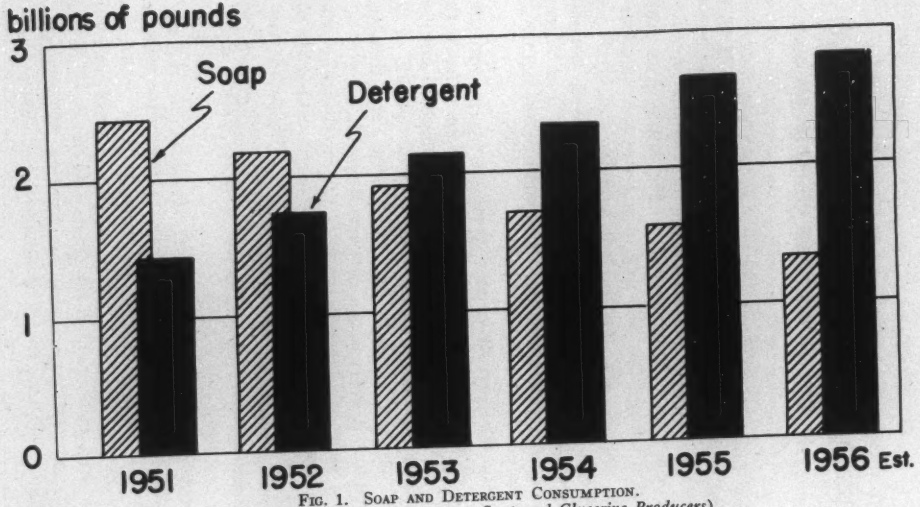


FIG. 1. SOAP AND DETERGENT CONSUMPTION.
(Source: Association of American Soap and Glycerine Producers)

of the active organic surfactant is usually removed. Thus, it remains to act in the finished water.

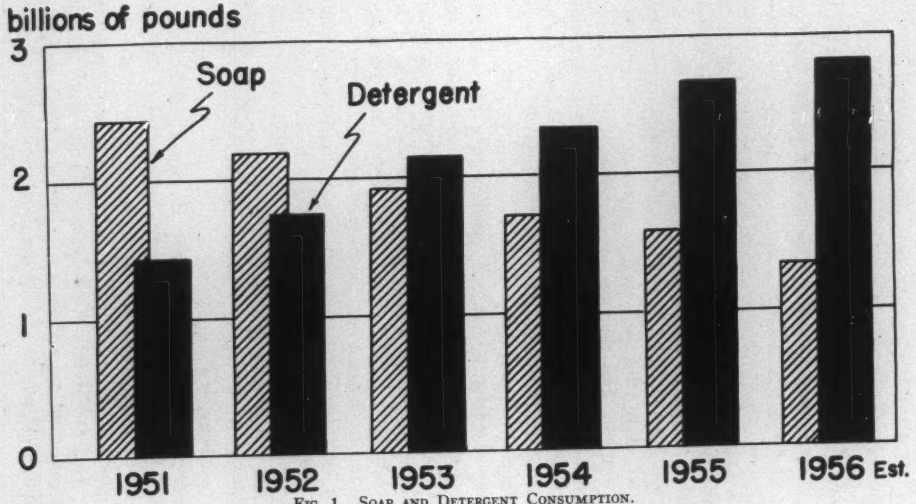
Synthetic detergents have captured the market largely because they do not precipitate when placed in hard water. This characteristic makes them a particular problem in sewage-treatment practice and the area of stream-pollution control. In cases where primary treatment of sewage is practiced, removal of synthetic detergents ranges from about 10 to 25%, which means that from 75 to 90% passes on into the river. The fate of the detergents in the rivers is a much-debated subject, but the fact that synthetic detergents have been identified in many river supplies which have had a history of sewage pollution (3) lends support to the belief that certain forms, at least, have a rather long life in natural waters. Simpson (4) has shown half-lives of 20 hours, 6 and 15 days for three different types under simulated river conditions.

In sewage-treatment practice, secondary methods of treatment, such as trickling filters or activated sludge, are used to reduce the organic content of settled sewage to very low levels. Will such treatment devices accomplish the same results with the synthetic detergents? This matter has been under intensive study in our laboratories during the past 4 years, and it is the purpose of this paper to summarize the results. Most people are willing to concede that, if destruction can be accomplished by activated-sludge treatment within a 4- or 5-hour contact time, such materials would have a relatively short life in river waters, and vice versa.

Synthetic Detergents

There are 3 types of synthetic detergents: anionic, cationic and nonionic. Since over 80% of the detergents used are of the anionic type, this discussion will be restricted to them. The anionic detergents are all sodium salts and ionize to yield Na^+ and a negative ion containing the active organic surfactant. Ordinary soap is an example of an anionic detergent but is not classed among the synthetic group.

The anionic synthetic detergents may be classed into two general groups: sulfates and sulfonates. The sulfates are inorganic esters, formed by action of sulfuric acid with aliphatic alcohols, and involve a C-O-S linkage. The sulfonates are compounds with a C-S linkage, formed by treating organic compounds which do not have OH groups



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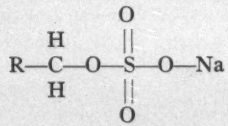
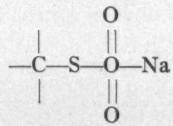
with sulfuric acid. As will be shown later, the nature of the linkage between carbon and sulfur determines to a considerable degree the ease with which anionic synthetic detergents are degraded by microorganisms.



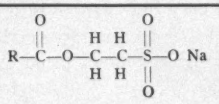
Sulfate Type



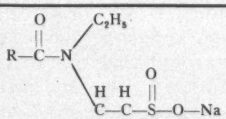
Sulfonate Type

Sulfates—In the U. S. sulfates are prepared almost entirely from lauryl alcohol, a primary alcohol with 12 carbon atoms. British practice involves the use of secondary alcohols, in addition. Both products are alike in their biochemical behavior.

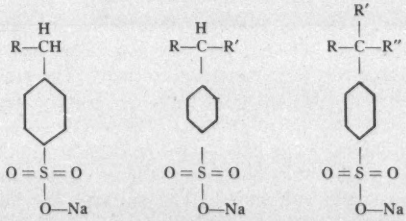
Sulfonates—Sulfonates are produced from several organic compounds, but 3 major groups predominate, as shown below.



Sulfonated Ester



Sulfonated Amide



Primary Secondary Tertiary

Sulfonated Alkyl Benzenes

Method of Study

Biological utilization of organic materials always involves use of oxygen, production of carbon dioxide, and multiplication or growth of microorganisms availing themselves of the energy in the compounds. Under aerobic conditions the extent and speed of the changes occurring can best be followed by measuring the oxygen utilized. Two techniques are commonly used: 1. The standard 5-day B.O.D. test or 2. manometric techniques, involving use of an apparatus such as the Warburg respirometer. The former is used where concentration levels are comparable to those experienced in natural river waters, and the latter when concentrations correspond to those of domestic sewage or higher.

Both the 5-day B.O.D. test and the Warburg respirometer were used to evaluate the susceptibility of synthetic detergents to biological oxidation in these investigations. In addition, 20-day B.O.D. tests were run on all substances which showed limited oxidation during a 5-day period. These were run by the large bottle method, developed by Orford (5).

The degree of degradation of the synthetic detergents was ascertained by 3 methods. Residual surfactant was measured by one of the colorimetric techniques available. The Methylene Blue method, as modified by Degens (6), was used most extensively. Since complete oxidation of the surfactants resulted in liberation of the sulfonate groups as sulfate ion, quantitative measurement of sulfates was performed. Infra-red analyses of end products were used to determine the extent of degradation of the alkyl benzene sulfonates.

Activated sludges were fed on mixtures of synthetic sewage plus surfactant, and on diets consisting of surfactant alone. The activated sludges served as sources of acclimated seed for the standard B.O.D. tests and for mass inocula in the Warburg studies.

Results of Investigations

Sulfates—Lauryl sulfate, *i.e.* n-dodecyl sulfate, was chosen for these studies. This surfactant exhibited a 5-day B.O.D. of 57.2% of the theoretical B.O.D., when ordinary sewage was used for seeding the dilution water. Warburg respirometer studies with unacclimated activated sludge showed an oxygen utilization of 59.7% of the theoreti-

cal value within a 6-hour period (Table 1). Both of these values are comparable to results obtained with a simple substrate, such as glucose. Therefore, it may be concluded that the alkyl sulfate type of surfactant will not ordinarily be a problem in public water supplies because of its ease of biological assimilation.

Sulfonates—Because of the wide variety of sulfonates used in compounding synthetic detergents for the retail trade, and because of differences in their susceptibility to biological degradation, it is necessary to consider the behavior of those surfactants in several categories.

1. *Sulfonated amides and esters*—The sulfonated amides and esters were found to behave in very much the same manner as sulfates. Both were found to exhibit 5-day B.O.D. values of 52 to 60% in the presence of ordinary sewage organisms, and both showed significant utilization of oxygen in the Warburg respirometer in contact with activated sludge during a 6-hour period (Table 1). Therefore, it may

TABLE 1
BIOLOGICAL OXIDATION OF CERTAIN ANIONIC SYNDETS

	5-Day B.O.D. (% of Theor.)	Activated Sludge 6-HR O_2 Demand (% of Theor.)
Sulfates		
Lauryl Sulfate	57.2	59.7
Sulfonated		
Amide	52.0	56.0
Ester	59.8	45.0

be concluded that sulfonated esters and amides will not survive in sewage-treatment plants or natural river waters under normal conditions, to cause trouble in public water supplies.

2. *Alkyl benzene sulfonates*—The alkyl benzene sulfonates, theoretically, can be of 3 types, depending upon the nature of the attachment of the benzene ring to the alkyl group, as previously illustrated. The primary alkyl benzene sulfonates are of no commercial significance as surfactants, because of their limited solubility. However, for theoretical reasons, they were included in the studies to complete the picture of how chemical structure influences biological assimilability of organic compounds.

(a) Primary alkyl benzene sulfonates.—Methyl, ethyl, propyl, butyl, octyl, decyl and dodecyl benzene sulfonates were subjected to study. All of these compounds were found to exhibit significant lag periods in the 5-day B.O.D. test, when using sewage seed, but showed in the order of 80% of the theoretical B.O.D. in 20 days' time. When acclimated seed was used, the 5-day values approached the normal range for readily assimilable soluble substrates (Table 2). Studies

TABLE 2
BIOLOGICAL OXIDATION OF PRIMARY ALKYL BENZENE SULFONATES

	5-Day[1] B.O.D. (% of Theor.)	Activated Sludge 6-HR O_2 Demand (% of Theor.)	Recovery of Sulfonate as $SO_4^=$ (%)
Methyl	54	37	93
Ethyl	50	39	99
Propyl	2	40	100
Butyl	39	44	97
Octyl	56	47	97
Decyl	36	48	98
Dodecyl	43	38	95

[1] Using acclimated seed.

with acclimated activated sludges in the Warburg respirometer showed the n-alkyl benzene sulfonates to be utilized at relatively rapid rates. Sulfate analyses showed essentially all the sulfonate group to be recoverable as sulfate ion, indicating complete dissimilation of the molecule. Infra-red analysis showed complete disappearance of characteristics related to alkyl benzene sulfonates (Figure 2).

Although the results obtained with the primary alkyl benzene sulfonates have little significance in the field of public water supplies, the data show that specialized organisms, not present in great numbers in natural sewage, are needed to initiate the destruction of these compounds. The data also show that, once such organisms are allowed to develop in sufficient quantities, the degradation of primary alkyl benzene sulfonates is rapid and complete.

(b) Secondary alkyl benzene sulfonates.—Secondary propyl, butyl, amyl, octyl, decyl, and tetradecyl benzene sulfonates were sub-

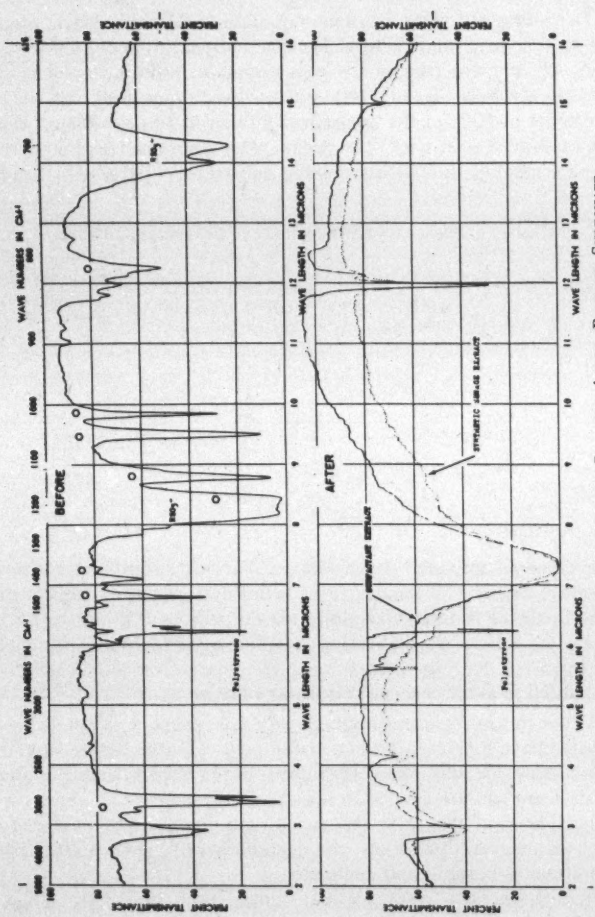


FIG. 2. INFRARED SPECTROGRAM OF PRIMARY ALKYL BENZENE SULFONATE.

jected to study in the same manner as the primary compounds. The behavior of these compounds was very similar to that of the primary compounds, except that the propyl, butyl and amyl compounds gave longer lag periods in the B.O.D. tests (Table 3), and more difficulty was experienced in developing activated sludges from them as the sole source of food. However, sulfate analyses and infra-red spectrograms run upon the activated-sludge effluents, using propyl, octyl, and decyl forms, showed that the sulfonate groups were largely converted to sulfate ion and that the alkyl benzene sulfonates were completely destroyed (Figure 3).

TABLE 3
BIOLOGICAL OXIDATION OF SECONDARY ALKYL BENZENE SULFONATES

	5-Day[1] B.O.D. (% of Theor.)	Activated Sludge 6-HR O_2 Demand (% of Theor.)	Recovery of Sulfonate as $SO_4^=$ (%)
Propyl	4	28	90
Butyl	2	3	3
Amyl	0	15	5
Octyl	30	53	96
Decyl	40	51	93
Tetradecyl	27	55	—

[1] Using acclimated seed.

Secondary alkyl benzene sulfonates, particularly keryl benzene sulfonate, have been used in retail products to a considerable extent in the past. However, the use of these compounds has been largely replaced by another product, derived from by-products of the petroleum industry, the propylene benzene sulfonates. It can be concluded from these studies that secondary alkyl benzene sulfonates could be a problem in public water supplies. The long lag period experienced in the B.O.D. studies shows that organisms capable of attacking the compound are not plentiful in natural water or sewage. Therefore, such materials could survive for long distances in rivers. This is substantiated by Simpson (4), who found such substances to have a half-life of 6 days in a natural river water. The results with activated sludge indicate that the majority, if not all, of the secondary alkyl sulfonates would be destroyed where sewage is subjected to such treatment.

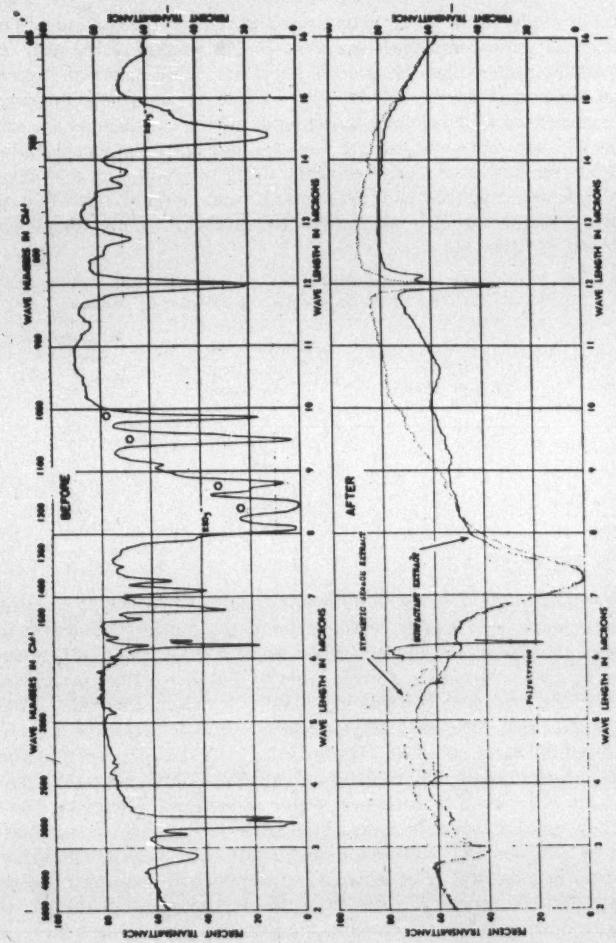


FIG. 3. INFRARED SPECTROGRAM OF SECONDARY ALKYL BENZENE SULFONATE.

(c) Tertiary alkyl benzene sulfonates.—The tertiary alkyl benzene sulfonates constitute the major form of the alkyl benzene compounds used in household detergent formulations at the present time. They are derived from propylene, a by-product of petroleum cracking and, in addition to being inexpensive, they possess excellent deterging properties. Due to their wide usage, they were subjected to exhaustive study, and the results are particularly significant.

Polypropylene benzene sulfonate, as produced for the synthetic detergent industry, consists mainly of a mixture of di-, tri-, tetra- and pentapropylene benzene sulfonates. For this reason it was deemed desirable to study each of the polymers separately, as well as the mixture. Samples consisting essentially of the di-, tri-, tetra- and pentacompounds were provided by the Continental Oil Co. of Ponca City, Okla. Tertiary butyl and amyl compounds were synthesized in our laboratory.

Results of the studies with the tertiary alkyl benzene sulfonates have shown them to be extremely resistant to biological attack. Long-term, 20-day B.O.D. studies with sewage seed and acclimated seed have shown essentially no oxygen usage. Oxidation studies in the Warburg respirometer have shown activated sludges to have little

TABLE 4
BIOLOGICAL OXIDATION OF TERTIARY ALKYL BENZENE SULFONATES

	5-Day[1] B.O.D. (% of Theor.)	Activated Sludge 6-HR O_2 Demand (% of Theor.)	Recovery of Sulfonate as $SO_4^=$ (%)
Butyl	0	4	0
Amyl	0	4	0
Dipropene	2	4	0
Tripropene	2	3	0
Tetrapropene	2	1	0
Pentapropene	0	1	0

[1] Using acclimated seed.

"stomach" for the compounds (Table 4). Attempts to develop activated sludges necessitated the development of a special rolling type of unit, to overcome foaming problems. In spite of this, it was found impossible to develop sludges that could be maintained on these

compounds as a sole source of food. Colorimetric tests showed little, if any, decrease in synthetic-detergent concentration after 24 hours' aeration with activated sludges, which had been receiving a similar diet for several days prior to the test. The sulfonate groups could not be recovered as sulfate ion. This is in direct opposition to the findings of House and Fries (7). Infra-red spectrograms of effluents from the activated-sludge units showed the presence of significant amounts of alkyl benzene sulfonates (Figure 4).

The results of the B.O.D. studies indicate that the propylene benzene sulfonates—in fact, all tertiary benzene sulfonates—can be expected to survive for great distances in rivers. This is in agreement with the findings of Simpson (4), who found a half-life of 15 days under simulated river conditions. The activated-sludge studies demonstrate that even our most potent treatment process is not effective in completing the destruction of this type of compound. Trickling filters would be even less effective. Thus, it might be concluded that the tertiary benzene sulfonates constitute the greatest threat to public water supplies of any of the anionic-type detergents. Also, because the anionic type of detergents constitutes over 80% of all synthetic detergents sold, it is quite evident that the tertiary alkyl benzene sulfonates deserve our special attention.

Discussion

The results of this investigation provide an excellent opportunity to speculate regarding the mode of biological degradation of the various anionic detergents in relation to chemical structure.

Sulfates—The alkyl sulfates are esters of sulfuric acid and possess the C-O-S bond. Because of the rapid nature of their attack by organisms native to sewage, it is likely that the first step in their degradation involves a simple hydrolysis to the alcohol and sulfuric acid from which they are formed. Since alcohols are readily oxidized by many bacteria, no time is lost in conversion to carbon dioxide, water and cell growth.

Amides and Esters—The sulfonated amides and esters are attacked at rates comparable to alkyl sulfates. In these cases also, the first step in breakdown of the syndet, probably, involves a simple hydrolysis of the ester, to form a fatty acid and a sulfonated alcohol,

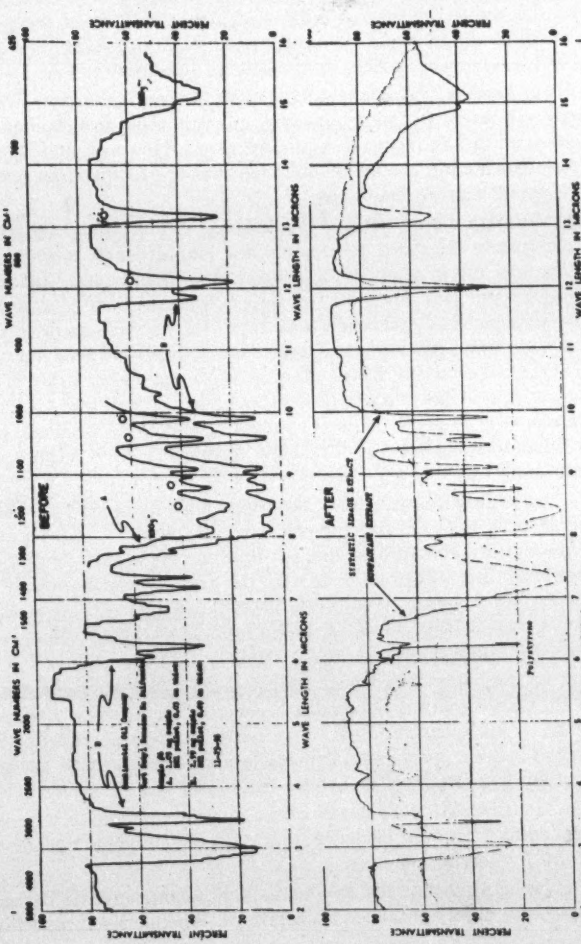


FIG. 4. INFRARED SPECTROGRAM OF TERTIARY ALKYL BENZENE SULFONATE.

and of the amide, to form a fatty acid and a sulfonated secondary amine. All products would be readily susceptible to further biological degradation, except, possibly, the sulfonated secondary amine.

Alkyl Benzene Sulfonates—The alkyl benzene sulfonates are essentially sulfonated hydrocarbons and, as such, they do not offer any easy point of attack by most microorganisms. However, it is known that terminal methyl groups of hydrocarbons are oxidized by certain bacteria under aerobic conditions.

1. Primary forms.—All of the primary alkyl benzene sulfonates were completely degraded to free sulfate ion, although initiation of oxidation was often delayed for several days when only organisms native to sewage were involved. However, when acclimated activated sludges were used, degradation was rapid. This demonstrates that when a significant population of organisms capable of attacking the terminal methyl group of the alkyl group is present, degradation of the alkyl group and of the benzene group is complete. Therefore, degradation of this type of alkyl benzene sulfonate presents no problem, provided organisms capable of attacking terminal methyl groups are present.

2. Secondary forms.—The secondary alkyl benzene sulfonates, in general, behaved quite like the primary compounds. It is necessary that organisms capable of oxidizing terminal methyl groups be present, and then oxidation will proceed as with the primary compounds.

3. Tertiary forms.—The tertiary alkyl benzene sulfonates were found to be quite resistant to oxidation, although limited amounts of oxygen were utilized in most cases. This is evidence that oxidation was started, probably at terminal methyl groups, but complete oxidation of the compound was impossible because of the absence of hydrogen on the tertiary carbon atom. As a result, further degradation involving the benzene group was impossible and, consequently, the sulfonate group was not freed as sulfate ion.

The fact that sulfonate groups of the tertiary compounds were not freed as sulfate ions is evidence that the C-S linkage cannot be severed by hydrolytic enzymes.

It is recognized that the tri-, tetra- and pentapropylene benzene sulfonates have highly branched alkyl groups. Whether such branching

in these groups is a deterrent to biological oxidation is not known. Further research is contemplated to clarify this point.

Conclusions

1. All anionic synthetic detergents, except the alkyl benzene sulfonates derived from propylene, are subject to complete biological degradation.

2. Degradation of anionic syndets which can be cleaved by hydrolytic enzymes (inorganic esters, esters and amides) is rapid and complete.

3. Degradation of the alkyl benzene sulfonates depends upon the presence of organisms capable of oxidizing terminal methyl groups to carboxyl groups.

4. Complete degradation of the alkyl benzene sulfonates occurs when the benzene group is attached to a primary or secondary carbon atom of the alkyl group.

5. Tertiary alkyl benzene sulfonates are not completely degraded by bacteria, because biological oxidation is blocked at the tertiary carbon atom.

6. The effect of branching in the alkyl groups of tri-, tetra- and pentapropylene benzene sulfonates on biological degradation could not be ascertained from these studies.

7. Water-supply problems related to synthetic detergents are most likely to be caused by polypropylene benzene sulfonates, due to their resistance to biological degradation and to their popularity among producers of retail products intended for household use.

References

1. Smith, R. S., Cohen, J. M., and Walton, G. "Effects of Synthetic Detergents on Water Coagulation." J. Am. Water Works Assoc., *48*, 55 (1956).
2. Howells, D. H., and Sawyer, C. N. "Effect of Synthetic Detergents on Chemical Coagulation of Water." Water & Sewage Works, *103*, 71 (1956).
3. Task Group Report, "Characteristics and Effects of Synthetic Detergents." J. Am. Water Works Assoc., *46*, 751 (1954).
4. Simpson, J. R., Bogan, R. H., and Sawyer, C. N. "Biochemical Behavior of Synthetic Detergents." Ind. Eng. Chem., *48*, 236 (1956).
5. Orford, H. E., Rand, M. C., and Gellman, I. "A Single Dilution Technique for B.O.D. Studies." Sewage & Ind. Wastes, *25*, 284 (1953).

6. Degens, P. N., Jr., van der Zee, H., and Kommer, J. D. "Anionic Detergents in Amsterdam Sewage." Sewage & Ind. Wastes, *25*, 24 (1953).
7. House, R., and Fries, B. A. "Radioactive ABS in Activated Sludge Sewage Treatment." Sewage & Ind. Wastes, *28*, 492 (1956).

ACKNOWLEDGMENT

This investigation was supported by a research grant, RG3650, from the National Institutes of Health, U.S. Public Health Service.

MEMOIR OF HORACE L. CLARK

Horace Little Clark of Alfred, Me., was born in Andover, Mass., on January 19, 1888, and had lived in Sanford, Me., for many years before moving to Alfred about seven years ago.

Mr. Clark was graduated from Phillips Exeter Academy in 1904 and from Massachusetts Institute of Technology in 1915 with a B.S. degree in Civil Engineering. His first engineering experiences were in the railroading and mining fields. In 1912, he went to Bolivia, S. A., as Sectional Engineer for the Antofagasta and Bolivia Railroad. In 1917 he went to Chile, where he served as Engineer in charge of railroad construction for the Chile Exploration Co. in Chuquicamata, as well as in other capacities at its mines.

After his return to the States in 1921, Mr. Clark held various responsible positions with the Ohio Marble Co., Piqua, O.; Metcalf & Eddy, Boston, Mass., and the Atlantic Public Utilities, Inc., New York, N. Y. From December, 1931, to August, 1945, he served as Superintendent and General Manager of the Sanford Water District.

In May, 1946, Mr. Clark went into consulting engineering in water works and sewerage and worked on many projects in Maine and New Hampshire.

In December, 1919, Horace Clark and Florence Baker of Exeter, N. H., were married in Cristobal, Canal Zone. Three daughters were born to them.

On coming to Sanford, Mr. Clark was active in community affairs, including the Girl Scout Camp and the Community Health Camp for underprivileged children. He was a member and past-president of the Rotary, Senior Deacon and Deacon of the North Parish Congregational Church for 19 years, and a Director of the Sanford Trust Co. since 1940.

He was a Registered Professional Engineer in Maine and New Hampshire, a member of the Boston Society of Civil Engineers, the New England Water Works Association since 1929, being president in

1943-1944, the American Water Works Association, the Maine Water Utilities Association, the New Hampshire Water Works Association, the Maine Association of Engineers, and the Sigma Alpha Epsilon Fraternity.

On Sunday, March 3, 1957, at the H. D. Goodall Memorial Hospital, after a long illness, the Engineer, the friend, the neighbor so many of us knew as Horace, passed away quietly in the presence of his wife.

EMERY S. LITTLEFIELD

PROCEEDINGS

April 1957 Meeting

Bridgeport Hydraulic Co., Bridgeport, Conn.

Thursday, April 18, 1957

The Southern New England meeting of the Association was held in Bridgeport, Conn., on April 18, 1957, with 241 members and guests in attendance.

The group met at Exit 52 of the Merritt Parkway and went in an escorted motorcade to inspect the following installations of the Bridgeport Hydraulic Co.: the Trap Falls Dam and Treatment Plant, the Housatonic Well Field and the Buck Hill Pumping Station. A reception, with Bridgeport Hydraulic Co. as host, was given the group on their return to the new Construction and Service Building, where luncheon was served.

President Edward L. Tracy introduced those at the head tables and called upon His Honor Jasper McLevy, Mayor of Bridgeport, who was most cordial in his welcome. Fred B. Silliman, President of Bridgeport Hydraulic Co., spoke briefly on the marking of the 100 years of service and growth of that company, and told of the plans for future developments.

A paper, entitled "Engineering and Design Problems in Connection with Controlled Access Highway Utility Relocations", was read by Kenneth E. Bender, Superintendent of Distribution, Bridgeport Hydraulic Co.

May 1957 Meeting

Hotel Wentworth-by-the-Sea, Portsmouth, N. H.

Thursday, May 16, 1957

The Association held its Northern New England meeting in Portsmouth, N. H., on Thursday, May 16, 1957. More than 160 members and their guests assembled at the Spaulding Turnpike entrance of the Portsmouth Air Force Base, where they boarded special busses for an escorted inspection tour of the Base.

The group then convened at the Hotel Wentworth-by-the-Sea, where luncheon was served.

After luncheon President Edward L. Tracy introduced those at the head table. Portsmouth's City Manager, Robert C. Violette, welcomed the assembly and extended a cordial invitation to return to that historic city.

Colonel Charles A. Dunn, Base Commander, 817th Air Base Group, read a paper, entitled "Portsmouth Air Force Base and Its Functions in Our Defense Program".

A paper on "New Portsmouth Air Force Base Water System" was read by Paul F. Howard, Whitman & Howard, Consulting Engineers, Boston, Mass.

INDEX OF ADVERTISERS

	Page
Badger Meter Mfg. Co.	Following front cover
B-I-F Industries, Inc.	Following front cover
Bingham & Taylor Corp.	Following front cover
Brown Co.	xviii
Caldwell Co., George A.	iv
Camp, Dresser & McKee	ii
Cast Iron Pipe Research Assn.	xxiii
Cement Lined Pipe Co.	xviii
Centriline Corp.	Following front cover
Chapman Co., R. E.	ii
Coffin and Richardson	ii
Crosby, Irving B.	ii
Cummins Diesel of New England, Inc.	Following front cover
Eddy Valve Co.	xii
Eureka Pipe Co., Inc.	xiv
Fairbanks, Morse & Co.	Following front cover
Fay, Spofford & Thorndike	ii
Flexible, Inc.	xviii
Ford Meter Box Co., The	Following front cover
Gunite Restoration Co., Inc.	ii
Haley & Ward	ii
Hays Mfg. Co.	xiii
Hazen & Sawyer	iii
Hersey Mfg. Co.	ix
Hilco Supply, Inc.	viii
Hydraulic Development Corp.	vii
Jerman, Daniel L.	iv
Keasbey & Mattison Co.	v
Kennedy Valve Mfg. Co.	xv
Knowles, Inc., Morris	ii
Layne-New York Co.	iii
Leadite Co.	Back cover
Leggette, Brashears & Graham	ii
Lock Joint Pipe Co.	Following front cover
Ludlow Valve Mfg. Co.	Following front cover
Maguire & Assoc., Chas. A.	iii
Maher Co., D. L.	iii
Metcalf & Eddy	ii
Mills Engineering Co., Inc.	xiv
Morris Knowles, Inc.	ii
Mueller Co.	Following front cover
National Water Main Cleaning Co.	x
Neptune Meter Co.	Following front cover
New England Pipe Cleaning Co.	xvi
Pierce-Perry Co.	iii
Pipe Founders Sales Corp.	xiv
Pirnie, Malcolm	iii
Pitometer Assoc., Inc., The	iii
Pittsburgh-Des Moines Steel Co.	Following front cover
Pittsburgh Equitable Meter Div.	Following front cover
Pollard Co., Inc., Joseph G.	Following front cover
Prescott & Sons, Inc., H. R.	xvi
Public Works Supply Co.	xviii
Rockwell Manufacturing Co.	Following front cover
Ross Valve Mfg. Co.	xvii
Smith and Norrington Engineering Corp.	iii
Smith Mfg. Co., The A. P.	Following front cover
Torrington Supply Co., Inc.	xviii
Turbine Equipment Co. of New England	Following front cover
U. S. Cast Iron Pipe & Foundry Co.	xxiv
Utilities Supply Corp.	viii
Wallace & Tiernan Co., Inc.	xi
Weston & Sampson	iii
White Construction Co., R. H.	xiv
Whitman & Howard	iii
Wood Co., R. D.	Following front cover
Worthington-Gamon Meter Div.	vi

(Classified index on page xxiii)

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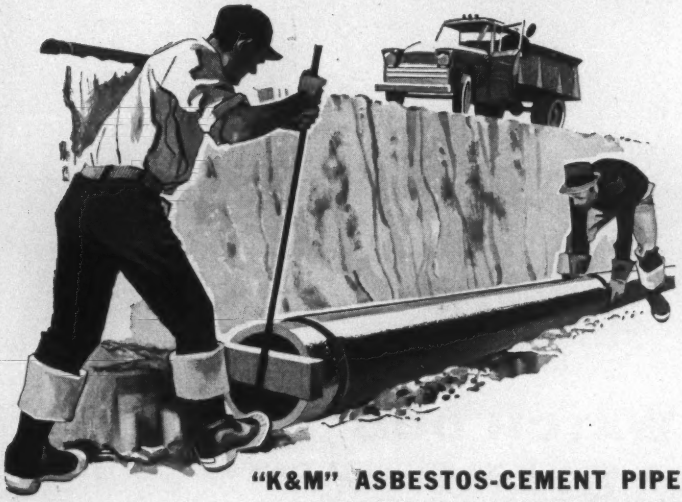

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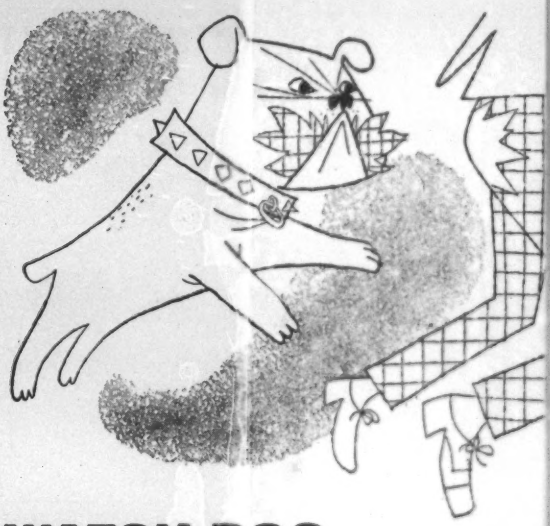

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ON GUARD 24 HOURS A DAY

Profits in water service today are measured in pennies. Worthington-Gamon WATCH DOG Water Meters guard your profits three vital ways:

Accuracy . . . provides precise measurement of water.

Simplicity . . . of design makes for ease of repair.

Durability . . when you invest in WATCH DOG Meters, you are assured of long life equipment.

The majority of large U.S. cities are using WATCH DOG Meters. Write today for detailed information, concerning your specific requirements. Representatives and offices in all principal cities.

WORTHINGTON-GAMON METER DIV

WORTHINGTON CORPORATION

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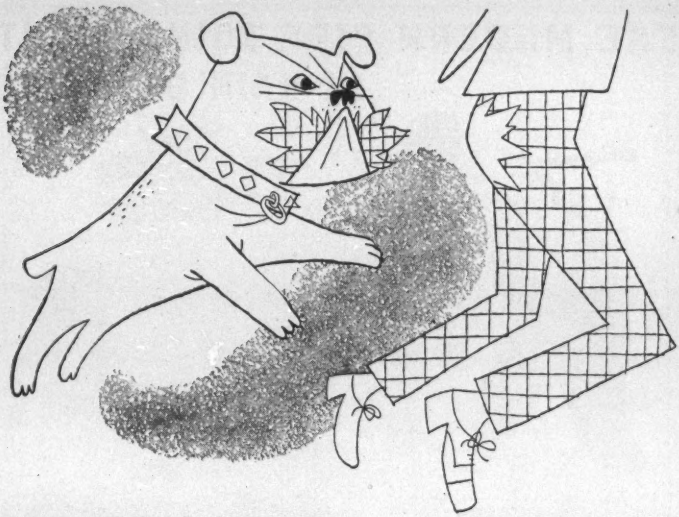
"The sign of value around the world"



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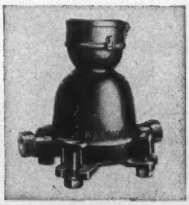

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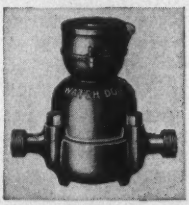

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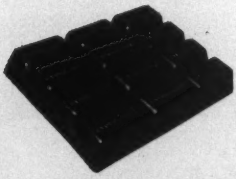

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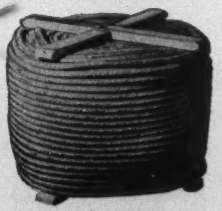
(LITTLEPIGS)

The same dependable compound in solid form — packed in 50 lb. cartons — 2 litters of pigs to the box — 24 easy-to-handle Littlepigs. Easier to ship, handle and store.



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(REELS)

The sanitary, bacteria-free joint packing. Easier to use than jute and costs about half as much. Insures sterile mains and tight joints.

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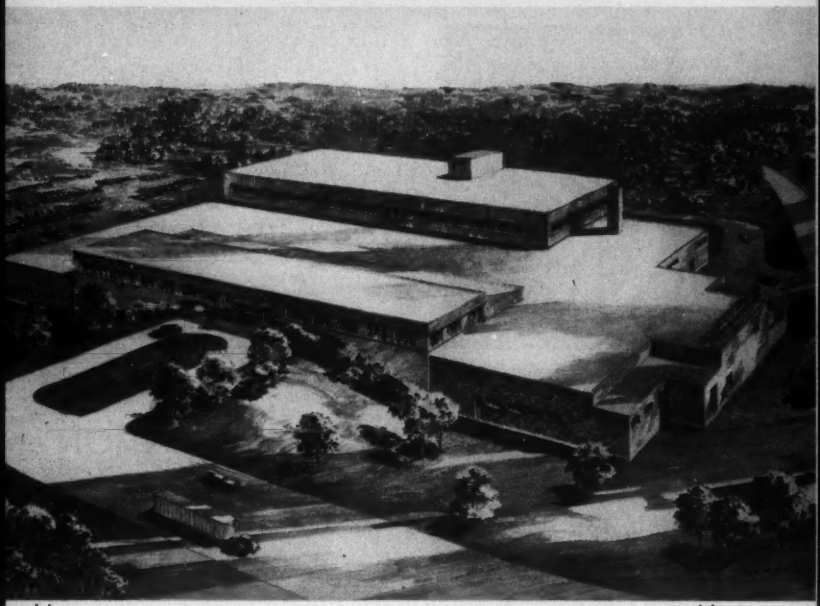

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IN THE UNITED STATES

ESTABLISHED 1859

HERSEY MANUFACTURING COMPANY

DEDHAM, MASS.

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NEW ENGLAND
WATER WORKS ASSOCIATION

on your 75th Anniversary

We are proud to salute the New England Water Works Association on their 75th year of progress and achievement in the Water Works field! And we're proud for another reason — it's National's 51st year in business. For us, it means over a half-century of progress increasing efficiency, carrying capacity and pressure of water mains all over the world!

Write us today for facts and information that shows how National's over 50 years of experience cleaning water mains can restore your system to at least 95% of its original rated capacity.

Call on National today!

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NOW... Dosage Automation

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W&T *Quality-Quantity Chlorinator*

Select the residual you want and the new W&T Quality-Quantity Chlorinator will automatically maintain that residual. Immediate sensing of any change in a water's chlorine demand—as well as flow—automatically controls chlorine feed rate to maintain a desired residual. That is Dosage Automation with the new W&T Quality-Quantity V-notch Chlorinator.

DOSAGE AUTOMATION OFFERS THESE FEATURES:

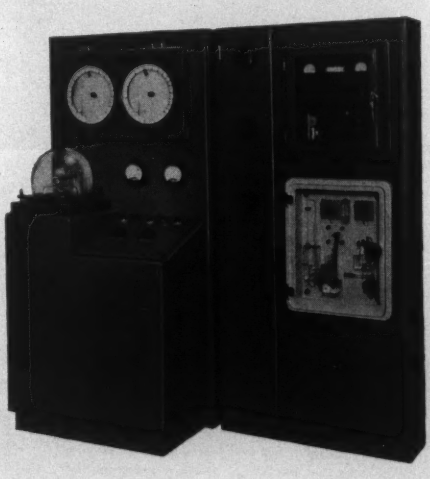
Maintains
a selected residual, free or total, with automatic dosage control.

Anticipates
changes in chlorine demand.

Controls
Chlorine feed up to a full 100 to 1 range at rates to 2000 pounds of chlorine per 24 hours.

Provides
a record of chlorine dosages in p.p.m. and chlorine feed rates in pounds per 24 hours.

Utilizes
the proven W&T V-notch Variable-Orifice for accurate, wide range chlorine feed.



For more information about this new type of chlorination system write for Bulletin S-118.

WALLACE & TIERNAN INCORPORATED

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62 YEARS' PERFECT SERVICE

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VALVES AND HYDRANTS

Photo courtesy of Mr. W. K. Sanders, Superintendent, Water and Light Department, Morrisville, Vermont

Morrisville, Vermont, installed the above EDDY Valve in a water main way back in 1895. When uncovered recently, it was working perfectly, needing only an easily obtained, easily installed packing to restore it to 100% efficiency.

On the basis of Eddy's long time record of continuous availability of replacement parts—and in the light of innumerable cases where EDDY valves and hydrants have served perfectly, needing no maintenance, for 20, 40, 60 years and longer—we feel justified in predicting *another* 62 years' service for the valve shown here.

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Send today for full data on the complete line of Eddy Valves, Hydrants and other waterworks' necessities. No obligation.

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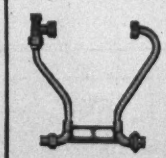

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ROUNDWAY CURB STOP

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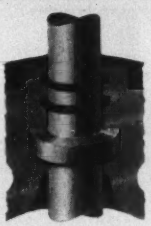
KENNEDY A.W.W.A. Gate Valves

Give You More Value For Your Valve Dollar . . .



O-RING SEALS

Provide excellent seal, prevent binding of stem and result in very easy valve operation. KENNEDY O-Rings are located above collar, permit repacking under pressure. Optional on KENNEDY non-rising stem A.W.W.A. valves.

KENNEDY Fig. 56
A.W.W.A. Standard Iron-Body Double-Disc Gate Valve, with Bell Ends.

STRONGER CONSTRUCTION

Rugged design and construction features iron that is 50% stronger than ordinary cast iron to keep KENNEDY Valves doing a better job over a longer, more dependable operating life.

KENNEDY manufactures a complete line of water works valves. Sizes range from 2" to 48" including non-rising stem and outside-screw-and-yoke valves. These valves feature the hook-and-wedge type disc mechanism for easier, better and more positive valve operation. A wide variety of pipe connections are available.

For maximum service life, for the greatest value for your valve dollar, specify KENNEDY valves and fire hydrants. Remember, KENNEDY means dependability in valves, fire hydrants and accessories.

Fig. 571

Fig. 561

Fig. 566

Fig. 566G

Fig. 566FTR

Write today for NEW A.W.W.A. Valve Bulletin

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FOR WATER WORKS MATERIAL, CALL

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OVER 40 YEARS OF
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QUALITY WATER WORKS SUPPLIES SINCE 1914

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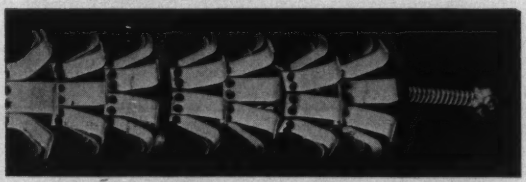
50 YEARS IN 50 MINUTES



FLEXIBLE'S PATENTED PRESSURE TOOL with its two counter rotating heads, saw tooth head and cutting and scraping heads removes in minutes the accumulation of years.

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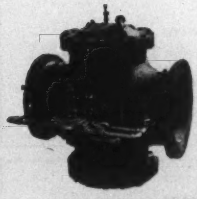
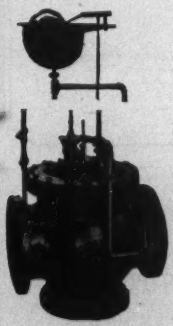


Controls elevation of water in tanks, basins and reservoirs

ALTITUDE VALVE
1. Single Acting
2. Double Acting

Maintains desired discharge regardless of change in rate of flow pressure

REDUCING VALVE
Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting.

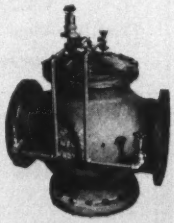
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

FLOAT VALVE

A self contained unit, with controls three or more automatic

COMBINATION VALVE
Combination automatic control both directions through the valve.

Maintains safe operating pressures for conduits, distribution and pump discharge



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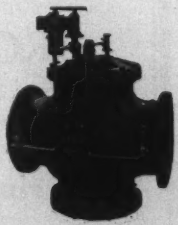
Electric remote control—solenoid or motor can be furnished



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Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

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CLASSIFIED DIRECTORY OF ADVERTISEMENTS

ASBESTOS-CEMENT PIPE.
Keasbey & Mattison Company v

BRASS GOODS.
Caldwell Co., George A. iv
Eureka Cement Lined Pipe Co. xiv
Hilco Supply viii
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
Torrington Supply Co., Inc. xvi
Utilities Supply Corp. viii

BROKEN PIPE REPAIR CLAMPS.
D. L. Jerman iv

CALKING MACHINERY AND TOOLS.
Hydraulic Development Corp. vii
Mueller Co. ..... Following front cover

CAST IRON PIPE. (See Pipe, Cast Iron.)

CEMENT LINED PIPE. (See Pipe, Cement Lined.)

CHEMICAL FEED APPARATUS.
B-I-F Industries ..... Following front cover
Wallace & Tiernan Co., Inc. xi

CHLORINATORS.
B-I-F Industries ..... Following front cover
Wallace & Tiernan Co., Inc. xi

CLAMPS.
D. L. Jerman iv

CLARIFIERS.
Mills Engineering Co., Inc. xiv

CLEANING WATER MAINS.
Flexible Pipe Cleaning Co. xviii
National Water Main Cleaning Co. x

COCKS, CURBS AND CORPORATIONS.
Caldwell Co., George A. iv
Eureka Cement Lined Pipe Co. xiv
Hays Mfg. Co. xiii
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
Utilities Supply Corp. viii

CONCRETE PIPE. (See Pipe, Concrete.)

CONTRACTORS' EQUIPMENT.
Hydraulic Development Corp. vii

CONTRACTORS.
Layne-New York Co., Inc. iii
Maher, D. L. Co. iii
White Construction Co., R. H. xiv

COUPLINGS, FLEXIBLE PIPE.
Caldwell Co., George A. iv
Public Works Supply Company xviii

CURB BOXES.
Bingham & Taylor Corp. ..... Following front cover
Caldwell Co., George A. iv
Eureka Cement Lined Pipe Co. xiv
Hays Mfg. Co. xiii
Hilco Supply viii
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
H. R. Prescott & Sons, Inc. xvi
Public Works Supply Company xviii
Utilities Supply Corp. viii

DIAPHRAGMS, PUMPS.
B-I-F Industries, Inc. ..... Following front cover
Joseph G. Pollard Co. ..... Following front cover

EJECTOR, PNEUMATIC.
Mills Engineering Co., Inc. xiv

ENGINEERS.
Camp, Dresser & McKee ii
Coffin & Richardson ii
Crosby, Irving B. ii
Fay, Spofford and Thorndike ii
Haley and Ward ii
Hazen and Sawyer iii
Knowles Morris, Inc. ii
Leggette, Brashears & Graham ii
Maguire & Associates, Charles A. iii
Metcalf and Eddy ii
Pirnie Engineers, Malcolm iii
Pitometer Associates, Inc., The iii
Smith and Norrington iii
Weston and Sampson iii
Whitman and Howard iii

ENGINES. (See Pumps and Pumping Engines.)

EQUIPMENT. (See Contractors' Equipment.)

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

FEED WATER FILTERS.
B-I-F Industries, Inc. ..... Following front cover
Ross Valve Mfg. Co., Inc. xvii
FILTRATION PLANT EQUIPMENT.
B-I-F Industries ..... Following front cover
Mills Engineering Co., Inc. xiv
FLAP VALVES.
Eddy Valve Co. xii
FLEXIBLE JOINTS.
U. S. Pipe and Foundry Co. xxiv
FURNACES.
Hilco Supply viii
Hydraulic Development Corp. vii
Leadite Co., The ..... Back cover
Mueller Co. ..... Following front cover
Pollard Co., Joseph G. ..... Following front cover
H. R. Prescott & Sons, Inc. xvi
Public Works Supply Company xviii
Utilities Supply Corp. viii
GATE VALVES. (See Valves.)
GEARS.
Mills Engineering Co., Inc. xiv
GENERATOR SETS
Cummins Diesel of New England, Inc. ..... Following front cover
GUNITE CONSTRUCTION.
Gunite-Restoration Co., Inc. ii
HOSE, SUCTION AND CONDUCTION.
H. R. Prescott & Sons, Inc. xvi
HYDRANTS, FIRE.
Caldwell Co., George A. iv
Eddy Valve Co. xii
Hilco Supply viii
Kennedy Valve Mfg. Co. xv
Ludlow Valve Mfg. Co. ..... Following front cover
Mueller Co. ..... Following front cover
H. R. Prescott & Sons, Inc. xvi
Public Works Supply Company xviii
Smith Mfg. Co., The A. P. ..... Following front cover
Utilities Supply Corp. viii
Wood, R. D., Co. ..... Following front cover
HYDRANTS, PUMPS.
Hilco Supply viii
Joseph G. Pollard Co. ..... Following front cover
H. R. Prescott & Sons, Inc. xvi
LEAD PIPE. (See Pipe, Lead.)
LIQUID CHLORINE.
Brown Co. xviii
METERS, OIL AND WATER.
Badger Meter Mfg. Co. ..... Following front cover
B-I-F Industries ..... Following front cover
Hersey Mfg. Co. ix
Neptune Meter Co. ..... Following front cover
Pipe Founders Sales Corp. xiv
Pittsburgh Equitable Meter Div. ..... Following front cover
Worthington-Gamon Meter Div. vi
METER COUPLINGS.
Badger Meter Mfg. Co. ..... Following front cover
Caldwell Co., George A. iv
Ford Meter Box Co. ..... Following front cover
Hays Mfg. Co. xiii
Hersey Mfg. Co. ix
Mueller Co. ..... Following front cover
Neptune Meter Co. ..... Following front cover
Public Works Supply Company xviii
Worthington-Gamon Meter Div. vi
METERS (Venturi Type.)
B-I-F Industries ..... Following front cover
METER BOXES.
Bingham & Taylor Corp. ..... Following front cover
Ford Meter Box Co. ..... Following front cover
Mueller Co. ..... Following front cover
Public Works Supply Company xviii
METER TESTERS.
Badger Meter Mfg. Co. ..... Following front cover
Ford Meter Box Co. ..... Following front cover
Mueller Co. ..... Following front cover
Neptune Meter Co. ..... Following front cover
Public Works Supply Company xviii
OIL ENGINES.
Fairbanks, Morse & Co. ..... Following front cover
PIPE, ASBESTOS-CEMENT.
Keasbey & Mattison Company v

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

PIPE, BRASS.
Caldwell Co., George A. iv
Hilco Supply viii
Pierce-Perry Co. iii
H. R. Prescott & Sons, Inc. xvi
Torrington Supply Co., Inc. xvi
Utilities Supply Corp. viii

PIPE, CAST IRON (and Fittings.)
B-I-F Industries ..... Following front cover
Bingham & Taylor Corp. ..... Following front cover
Cast Iron Pipe Research Association xxiii
Hilco Supply viii
Pipe Founders Sales Corp. xiv
H. R. Prescott & Sons, Inc. xvi
U. S. Pipe and Foundry Co. xxiv
Utilities Supply Corp. viii
Wood, R. D., Co. ..... Following front cover

PIPE, CEMENT LINED.
Cast Iron Pipe Research Association xxiii
Cement Lined Pipe Co. xviii
Eureka Cement Lined Pipe Co. xiv
Pipe Founders Sales Corp. xiv
U. S. Pipe and Foundry Co. xxiv
Utilities Supply Corp. viii

PIPE CLEANING
New England Pipe Cleaning Co. xvi

PIPE, COATING AND LININGS.
Centriline Corp. ..... Following front cover

PIPE, CONCRETE.
Lock Joint Pipe Co. ..... Facing front cover

PIPE CUTTING MACHINES.
Caldwell Co., George A. iv
Pollard Co., Joseph G. ..... Following front cover
Smith Mfg. Co., The A. P. ..... Following front cover

PIPE JOINTING MATERIAL.
Caldwell Co., George A. iv
Hilco Supply viii
Hydraulic Development Corp. vii
Leadite Co., The ..... Back cover
Utilities Supply Corp. viii

PIPE, LEAD.
Pierce-Perry Co. iii

PIPE LINING.
Cement Lined Pipe Co. xviii
Centriline Corp. ..... Following front cover

PIPE, PRESTRESSED CONCRETE.
Lock Joint Pipe Co. ..... Facing front cover

PIPE REPAIR CLAMPS.
D. L. Jerman iv

PIPE, WROUGHT IRON AND STEEL.
Pierce-Perry Co. iii
Torrington Supply Co., Inc. xvi

PLUG VALVES.
Eddy Valve Co. xii
Hays Mfg. Co. xiii
Mueller Co. ..... Following front cover
Pittsburgh Equitable Meter Div. ..... Following front cover

PITOMETERS.
Pitometer Associates, Inc., The iii

PORTABLE AIR COMPRESSORS. (See Air Compressors.)

PRESSURE REGULATORS.
Hilco Supply viii
Mueller Co. ..... Following front cover
Pittsburgh Equitable Meter Div. ..... Following front cover
H. R. Prescott & Sons, Inc. xvi
Ross Valve Mfg. Co., Inc. xvii

PROVERS, WATER.
Badger Meter Mfg. Co. ..... Following front cover
Ford Meter Box Co. ..... Following front cover

PUMPS AND PUMPING MACHINES.
Cummins Diesel of New England, Inc. ..... Following front cover
Fairbanks, Morse & Co. ..... Following front cover
Layne-New York Co., Inc. iii
Hilco Supply viii
Maher Co., D. L. iii
Mills Engineering Co., Inc. xiv
Joseph G. Pollard Co. ..... Following front cover
H. R. Prescott & Sons, Inc. xvi
Ross Valve Mfg. Co., Inc. xvii
Turbine Equipment Co. ..... Following front cover
White Construction Co., R. H. xiv

RATE CONTROLLERS AND GAUGES.
Badger Meter Mfg. Co. ..... Following front cover
B-I-F Industries ..... Following front cover

REDUCERS, SPEED.
Mills Engineering Co., Inc. xiv

REPAIR CLAMPS.
D. L. Jerman iv

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

SHEAR GATES.
Eddy Valve Co. xii
Mueller Co. ..... Following front cover
SLEEVES AND VALVE TAPPINGS.
Caldwell Co., George A. iv
Eddy Valve Co. xii
Hilco Supply viii
Ludlow Valve Mfg. Co. ..... Following front cover
Mueller Co. ..... Following front cover
H. R. Prescott & Sons, Inc. xvi
Public Works Supply Company xviii
Smith Mfg. Co., The A. P. ..... Following front cover
Utilities Supply Corp. viii
STEEL PLATE WORK.
Pittsburgh-Des Moines Steel Co. ..... Following front cover
STRAINERS.
Mills Engineering Co., Inc. xiv
SUPPLIES AND TOOLS.
Caldwell Co., George A. iv
Hilco Supply viii
Hydraulic Development Corp. vii
Leadite Co., The ..... Back cover
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
Pollard Co., Joseph G. ..... Following front cover
H. R. Prescott & Sons, Inc. xvi
Public Works Supply Company xviii
TAPPING MACHINES.
Caldwell Co., George A. iv
Hays Mfg. Co. xiii
Mueller Co. ..... Following front cover
Smith Mfg. Co., The A. P. ..... Following front cover
TANKS, STEEL.
Pittsburgh-Des Moines Steel Co. ..... Following front cover
TAPPING SLEEVES. (See Sleeves and Valves, Tappings.)
VALVE BOXES.
Bingham & Taylor Corp. ..... Following front cover
Caldwell Co., George A. iv
Eddy Valve Co. xii
Hilco Supply viii
Kennedy Valve Mfg. Co. xv
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
Pipe Founders Sales Corp. xiv
H. R. Prescott & Sons, Inc. xvi
Public Works Supply Company xviii
Smith Mfg. Co., The A. P. ..... Following front cover
Utilities Supply Corp. viii
Wood, R. D., Co. ..... Following front cover
VALVE AND GATE GENERATORS.
Mills Engineering Co., Inc. xiv
VALVE INSERTING MACHINES.
Mueller Co. ..... Following front cover
Smith Mfg. Co., The A. P. ..... Following front cover
VALVES, CHLORINE.
Wallace & Tiernan Co., Inc. xi
VALVES, GATE.
Caldwell Co., George A. iv
Eddy Valve Co. xii
Hilco Supply viii
Kennedy Valve Mfg. Co. xv
Ludlow Valve Mfg. Co. ..... Following front cover
Mueller Co. ..... Following front cover
Pierce-Perry Co. iii
H. R. Prescott & Sons, Inc. xvi
Public Works Supply Company xviii
Smith Mfg. Co., The A. P. ..... Following front cover
Torrington Supply Co., Inc. xvi
Utilities Supply Corp. viii
Wood, R. D., Co. ..... Following front cover
VALVES, REGULATING.
Mueller Co. ..... Following front cover
Ross Valve Mfg. Co., Inc. xvii
WASH FOUNTAINS.
Mills Engineering Co., Inc. xiv
WATER-PROOFING.
Gunite Restoration Co., Inc. ii
WATER WASTE DETECTION.
Pitometer Associates, Inc., The iii
WELLS, GRAVEL, FILTER AND DRIVEN.
Layne-New York Co., Inc. iii
Maher Co., D. L. iii
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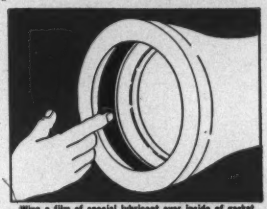
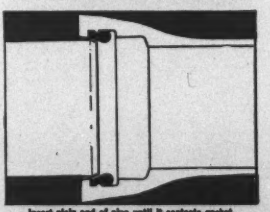
TYTON

ONLY FOUR SIMPLE ACTIONS

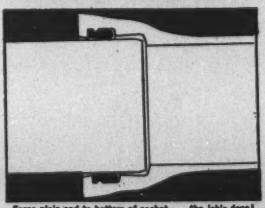
Insert gasket with groove over head in gasket seat



Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket . . . the job's done!

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